

NATIONAL RESEARCH COUNCIL

AN EVALUATION OF ALTERNATIVE
WET PEAT MINING SYSTEMS

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ABSTRACT

Vast areas occupied by peatlands in Canada are the second largest in the world after the U.S.S.R. Therefore it comes as no surprise that the Canadian Government attributes more and more importance to R & D studies whose task is to determine the feasibility of using peat in energy production. The development of suitable mining methods for both undrained and drained bogs, without undesirable environmental effects and a maximal seasonal yield of peat feedstock of quality suitable for further treatment at a fuel peat processing plant, is one of the tasks undertaken in recent research studies and projects.

Monenco's Peat Group has recently studied various wet peat mining systems and has developed several novel methods. One new method suggested for small-scale applications is based on the use of an amphibious dredge manufactured in the Netherlands by Konijn. All of the equipment required for peat excavation and pumping is mounted on the amphibious machines. Another system, similar to the hydropeat mining method, is based on the use of modern technology and involves a special peat slurry pump mounted on a barge. A peat slurry is produced by hydro monitors and is pumped to the peat processing plant. The various systems described are designed for annual capacities ranging from 50,000 to 1,000,000 tonnes (50% m.c.).

INTRODUCTION

In recent years, much effort has been undertaken to develop peat processing methods capable of accepting peat in a slurry form and yielding saleable products. Considerable progress has been made and several processes are reported available for commercial use. However, a paucity of information has existed on mining methods suitable to prepare fuel peat in a slurry form, although wet peat mining was practiced extensively in the U.S.S.R. for about fifty years. Some recent studies have been carried out considering the use of large-scale dredging technology for peat mining, but the methods are yet largely unproven for fuel peat production and no factual information was included on peat slurry rheology or pumping characteristics.

The statement of work for the project summarises the objectives of the study. It included the following:

"In order to review and assess the potential of wet peat mining systems for use in Canadian conditions; and to study mining systems involving excavation and transport of in-situ drained peat (medium/large scale processing) or removal of a 2 to 3% pumpable slurry (by other than cutter-suction dredging) in undrained peat (small/medium scale processing), the Contractor shall perform the following:

Task 1:

Review available literature.

Task 2:

Perform a technical assessment of the various mining methods and equipment; determine the compatibility of the above with bog surface conditions (including weather) and with product end-use. Note that products of wet mining operations shall be assessed in relation to the required feedstock quality of various peat processes.

The application of slurry pipelines and pumping technology (for wet macerated peat) and the requirements (in terms of equipment design and mobility aspects) for continuous (or near-continuous) operation on the bog surface shall be considered in detail.

Task 3:

Evaluate transport systems (on-bog to adjacent processing plant) and pumping aspects specifically related to peat.

Task 4:

Select a system best suited to Canadian fuel peat production (identifying assumptions influencing the selection). Provide cost information, including capital and operating costs, economies of scale, and equipment lists (mobile and fixed; including capacity ratings for conveying wet peat and for pipeline systems).

Task 5:

Prepare interim and final reports to include a technical and economic assessment of the wet mining techniques; a comparison of wet mining and dry mining economics; and recommendations from the most suitable methods."

As with most things, even the study of wet peat mining techniques is not new. It was reported by the monks near Utrecht in 1113 A.D. that both "white" and "black" peat was mined by hand from wet bogs using a special "toothed" bucket. After mining, the people mixed and pressed the raw peat using their feet and formed the peat by hand into lumps for drying. The first patent on a method to mine peat from water was taken by the Frenchman Chambre in 1568, who received a permit to use his method in France for a thirty year period.

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

1. During the course of the study, considerable information on actual wet peat mining systems used previously, or in current use, was reviewed. Of particular interest was the extensive Russian experience in wet peat mining and peat slurry pumping which was practiced from about 1915 until the early 1960's, nearly fifty years. Approximately 10 million tonnes (air-dried peat) was produced annually in the USSR by wet mining methods during the early 1950's.
2. The Russian wet peat mining system (Hydropeat) was discontinued in the early 1960's in favour of dry mining (milled) methods. Although the system was not well mechanized the principal reasons for discontinuance were related to the drying and subsequent harvesting operations which had a high manpower requirement, many moves and physical changes associated with the pipeline manipulation for the peat slurry spreading operation. Solar drying and harvesting was not required for the applications of wet mining investigated in the study.
3. Unique to this study is an attempt to discuss in detail the important characteristics of peat (moisture content, degree of decomposition, peat type, ash content, stumps content, etc) and their effects on the various mining processes considered, including their relationship to the key peat slurry pumping parameters. For instance, the dependency of solids concentration (a key peat slurry pumping parameter directly related to output) on factors such as peat type and degree of decomposition has been discussed in detail.
4. In selecting wet peat mining methods for further detailed assessment, only methods which could fill certain requirements were chosen. The requirements included: production of a standard quality of feedstock (for use in a processing plant for fuel production), utilization of equipment currently commercially available, effective peat recovery, etc.
5. The size of operations considered in this report were somewhat smaller scale than systems previously studied by others (e.g. recent peat dredging studies). Small-scale peat operations were considered to be about 50,000 tonnes per year, medium-scale from 250,000 to 500,000 tonnes per year, and large-scale operations up to 1 million tonnes per year, (all air-dried peat at 50% moisture content).

6. Four wet peat mining methods were selected for each case, i.e. for the undrained and drained peatland situations. The eight methods are outlined in Figures 3-1 and 4-1. The various methods were described and the advantages and disadvantages of each were discussed. Final selection of the most suitable method for each case (i.e. for undrained and drained peatland) took into consideration the following mining and feedstock requirements:

- mining: peat and peatland characteristics (peat type, peat quality, size of deposit, moisture content, peat depth, degree of decomposition, ash content, stumps content).
- feedstock: quality of the peat slurry as a feedstock to the process plant (optimum solids content, maximum pumping capacity, minimum pipeline pressure losses, high quality slurry, preparation characteristics).

7. For the final selection of a suitable method for each case (i.e. undrained and drained peatlands), a number of factors (15) were listed (technical, economic, environmental, etc.) and given a numerical weighting to indicate relative importance in the selection of a mining method. The various methods were then given a score for each factor resulting in a final ranking of the methods. The method which received the highest ranking was selected for further economic analysis.

In the case of the undrained peatland, the preferred method, selected as described above, was considered to be the bulk peat excavation by Amphidredge method. For drained peatlands, the slurry pump dredge system received the highest ranking.

8. For the wet peat mining of undrained peatlands the bulk peat excavation by Amphidredge appeared to have some distinct technical advantages related primarily to the flexibility and maneuverability of the Amphidredge machine. The equipment is self-propelled (it walks like a turtle) and has a minimal depth of water requirement for navigation (i.e. extensive flooding of the peatland surface is not required). The current model has a backhoe mounted to carry out excavation which tends to limit output.

9. The wet peat mining of drained (or partially-drained) peatlands using the slurry pump dredge system represents an attempt to take two key elements of the previous Hydropeat method (the hydro monitors and peat slurry pump) and modify and upgrade the equipment and combine it with other North American technology to produce a successful high capacity mining system. It was known that hydromonitors are effective on peat and that the

specially-designed peat slurry pump could produce favourable peat slurry characteristics to achieve optimal peat slurry pumping conditions. It was also necessary to locate a craft for mounting the equipment which could operate under conditions of minimal draft (e.g. large Amphidredge or hover barge) to maintain the required solids content and operate on drained or partly drained peatland.

10. To achieve optimum peat slurry pumping conditions (e.g. maximum pumping capacity, maximum pumping distance, minimum pipeline diameter) factors such as solids content, viscosity, flow velocity and pressure losses are considered. It is possible to determine these parameters using information and peat slurry pumping calculating methods previously developed in the USSR. A certain amount of correlation between European and Canadian peat data collection systems, and the development of new laboratory methods, is required to meaningfully utilize the existing European peat slurry pumping data.
11. For actual wet peat mining operations, it is recommended that a special peat slurry pump of suitable construction be manufactured which can achieve the high quality slurry preparation characteristics (i.e. the required degree of grinding, cutting and mixing of the peat slurry) as well as pumping the peat slurry a maximum distance.
12. Preliminary cost calculations were performed on the two mining methods considered best suited for undrained and drained peatlands. A levelized unit cost (including capital and operating costs) was calculated for the bulk peat excavation by Amphidredge method (used for undrained peatland) and resulted in a cost of \$30.20/tonne (equivalent 50% moisture content basis). Similarly, a levelized unit cost was calculated for the slurry pump dredge method and gave a result of \$6.68/tonne (equivalent 50% moisture content basis). The annual production rates determined for the two selected cases were 50,000 tonnes and 250,000 tonnes air dried (equivalent 50% moisture content basis), respectively.
13. Although mining on undrained peatland requires little surface preparation or drainage in advance of mining, especially compared to dry mining techniques, it was found that the equipment requirements for operating on the undrained peatland (bulk peat excavation by Amphidredge) resulted in a relatively high capital cost per installed unit capacity as compared to the system selected for the drained peatland (slurry pump dredge). As well, it appeared that the bulk peat excavation method selected was too small in capacity and required approximately the same size labour force as compared to the higher production slurry pump dredge method. The flexibility and maneuverability of the Amphidredge equipment on peatland surfaces appeared impressive, and an investigation into refinements of the wet mining technique using this equipment is probably warranted.

14. A comparison of technical and economic factors showed certain advantages of wet peat mining methods over dry methods such as higher unit capacity, higher yield from a cubic meter of raw peat, less active surface area requirements and less manpower. However, in the case of comparison with the milled peat method (a dry mining method), the total power requirement per 1000 tonnes air-dried peat was higher for the wet mining methods.
15. Only an introduction into the field of peat slurry pumping has been possible within the scope of the study. It is suggested further investigations into peat slurry rheology be initiated, utilizing the considerable existing European information to verify the assumptions and findings of this report.

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Le présent rapport a été rédigé par le Monenco's Peat Group. M. G.W. Mankinen et M. B. Gelfer (les principaux auteurs) ont reçu le concours de M. J. Radforth, pour le caractère praticable des tourbières et les moyens de transport à utiliser, et du Professeur M.E. Charles pour les essais rhéologiques en laboratoire sur la tourbe.

RÉSUMÉ

Le Canada est le deuxième pays au monde après l'URSS pour la superficie occupée par les tourbières. Il est donc naturel que le gouvernement canadien accorde une place de plus en plus importante aux études de R et D dont l'objectif est de déterminer l'applicabilité de l'exploitation de la tourbe comme source de combustible. Les recherches et les projets entrepris récemment visent à élaborer des méthodes appropriées d'exploitation de tourbières drainées et non drainées sans altérer l'environnement, et à obtenir un rendement saisonnier maximal d'une tourbe dont la qualité permettrait un traitement plus poussé en usine.

Le Monenco Peat Group a récemment étudié différents systèmes d'exploitation par voie humide et a mis au point plusieurs méthodes nouvelles. L'une de ces méthodes destinée à des applications à petite échelle consiste à utiliser une drague amphibie fabriquée aux Pays-Bas par le Groupe Konijn. Tout le matériel nécessaire à l'excavation et au pompage est monté sur des machines amphibies. Un autre système, semblable à la méthode d'exploitation de la tourbe hydratée, utilise des techniques modernes et une pompe spéciale montée sur une barge pour aspirer la tourbe en suspension. La tourbe en suspension est produite par des "hydro monitors" et est pompée jusqu'à l'usine de traitement. Les différents systèmes décrits ont une capacité annuelle nominale allant de 50 000 à 1 000 000 tonnes (teneur en humidité de 50 p. cent).

INTRODUCTION

Au cours des dernières années, on s'est efforcé de mettre au point des méthodes permettant de transformer une suspension de tourbe en produits commercialisables. On a réalisé d'importants progrès et, selon la littérature, plusieurs procédés seraient utilisables à l'échelle commerciale. Cependant, la documentation sur les méthodes d'exploitation permettant d'obtenir une tourbe combustible en suspension est assez pauvre, même si L'URSS exploite la tourbe par voie humide de façon extensive depuis environ cinquante ans. Certaines études récentes ont porté sur l'utilisation de techniques de dragage à grande échelle pour exploiter la tourbe, mais on ignore encore si ces méthodes peuvent produire une tourbe combustible et on ne dispose d'aucune donnée réelle sur la rhéologie de la tourbe en suspension ou sur ses caractéristiques de pompage.

La description des travaux pour le projet résume les objectifs de l'étude. Voici ce qu'elle précisait entre autres:

"en vue d'examiner et d'évaluer la possibilité d'utiliser des systèmes d'exploitation par voie humide dans les conditions prévalant au Canada; et en vue d'étudier des systèmes d'exploitation comportant l'excavation et le transport in situ de tourbe drainée (traitement à moyenne/grande échelle) ou le transport d'une suspension de 2 à 3% que l'on peut pomper (par d'autres moyens que par drague suceuse munie de cutters), d'une tourbe non drainée (traitement à moyenne/petite échelle), l'entrepreneur doit:

- 1) Examiner la littérature disponible sur le sujet
- 2) Effectuer une évaluation technique des différentes méthodes et du matériel d'exploitation; déterminer si les méthodes et le matériel sont compatibles avec les conditions à la surface de la tourbière (y compris les conditions météorologiques) et avec l'utilisation finale ou produit. Il y a lieu de noter que les produits d'exploitation de la tourbe par voie humide doivent être évalués en tenant compte de la qualité requise de la matière première pour les différents procédés d'exploitation.

Il faut examiner en détail l'application de pipelines et de techniques de pompage de suspensions de tourbe (dans le cas d'une tourbe humide macérée), ainsi que les exigences (en termes de la conception du matériel et de sa mobilité) relatives à une exploitation continue (ou presque continue) à la

surface de la tourbière.

3) Évaluer les systèmes de transport (de la tourbière à l'installation de traitement) et les caractéristiques de pompage concernant spécifiquement la tourbe.

4) Choisir le système le mieux approprié à la production de tourbe combustible au Canada (en indiquant les hypothèses influant sur ce choix). Fournir des données sur les coûts d'exploitation, les économies d'échelle et les listes de matériel (mobile et fixe; y compris la capacité de transport de la tourbe humide et la capacité des systèmes par pipeline).

5) Rédiger des rapports provisoires et finals comportant, entre autres, une évaluation technique et économique des procédés d'exploitation, une comparaison de la rentabilité de l'exploitation par voie humide et par voie sèche et des recommandations tirées des méthodes qui conviennent le plus."

Comme la plupart des choses, l'étude des techniques d'exploitation de la tourbe humide n'est pas nouvelle. Selon des moines vivant près d'Utrecht en 1113 après J.-C. on extrayait manuellement de la tourbe "blanche" et "noire" dans des tourbières humides à l'aide d'un seau "denté". Après l'extraction, on mélangeait et on pressait la tourbe brute avec les pieds puis on formait avec les mains des mottes que l'on faisait sécher. Le premier brevet d'exploitation de la tourbe humide a été accordé au français M. Chambre en 1568, à qui l'on a octroyé le droit d'utiliser cette méthode en France pendant trente ans.

RÉSUMÉ, CONCLUSIONS ET RECOMMANDATIONS

1. Au cours de l'étude, on a examiné de nombreuses données sur les systèmes réels d'exploitation de tourbe humide utilisés auparavant ou en cours d'utilisation. Il faut noter tout particulièrement l'expérience de la Russie qui a exploité la tourbe humide et pompé la tourbe en suspension de 1915 environ jusqu'au début des années 1960, soit durant près de cinquante ans. Au début des années 1950, la production annuelle de tourbe par voie humide en URSS se chiffrait approximativement à 10 millions de tonnes (tourbe séchée à l'air).
2. En URSS, on a abandonné le système d'exploitation de la tourbe par voie humide (tourbe hydratée) au début des années 1960 en faveur de méthodes par voie sèche (tourbe broyée). Même si le système ne demandait pas une

mécanisation poussée, il a été abandonné principalement parce que le séchage et la récolte exigeaient une main-d'oeuvre importante, ainsi que de nombreux déplacements et modifications physiques associées aux canalisations servant à épandre la tourbe en suspension. L'exploitation par voie humide examinée au cours de l'étude ne nécessite ni séchage au soleil ni récolte.

3. Contrairement aux autres, la présente étude examine en détails les caractéristiques importante de la tourbe (humidité, degré de décomposition, type de tourbe, teneur en cendres, quantité de souches, etc.) et leurs effets sur les différents procédés d'exploitation examinés, entre autres leur relation avec les paramètres clés du pompage de la tourbe en suspension. Par exemple, on a étudié en détail la relation entre la concentration de solides (un paramètre clé du pompage de la tourbe en suspension, qui est directement relié à la production) et des facteurs comme le type de tourbe et le degré de décomposition.
4. On n'a choisi que des méthodes susceptibles de satisfaire certaines exigences, en vue d'évaluer de façon plus approfondie les méthodes d'exploitation de la tourbe par voie humide. Voici certaines de ces exigences: production d'une qualité courante de matière première (destinée à la transformation combustible), utilisation du matériel actuellement disponible sur le marché, récupération efficace de la tourbe, etc.
5. Le présent rapport examine des opérations à plus petite échelle que celles des systèmes examinés dans des rapports précédents (p. ex. les études récentes sur le dragage de la tourbe). L'exploitation de la tourbe à petite échelle produit environ 50 000 tonnes par année, l'exploitation à moyenne échelle, de 250 000 à 500 000 tonnes par année, et l'exploitation à grande échelle, 1 million de tonnes par année (tourbe séchée à l'air, d'une teneur en humidité de 50 p. cent).
6. Dans chaque cas, soit dans les tourbières non drainées et drainées, on a choisi quatre méthodes d'exploitation par voie humide. Les huit méthodes sont illustrées aux Figures 3-1 et 4-1. On décrit les diverses méthodes et on en étudie les avantages et les inconvénients. Le choix final de la méthode la mieux appropriée à chaque cas (soit les tourbières non drainées et drainées) tenait compte des exigences suivantes relatives à l'exploitation et aux matières premières:
 - exploitation: caractéristiques de la tourbe et de la tourbière (type de tourbe, qualité de la tourbe, importance du dépôt, teneur en humidité, profondeur, degré de décomposition, teneur en cendres, nombre de souches).

- matières premières: qualité de la tourbe en suspension utilisée comme matières premières pour le traitement (teneur optimale en solides, capacité maximale de pompage, pertes minimales de pression dans les canalisations, suspension de grande qualité, caractéristiques de préparation).

7. En vue de choisir une méthode appropriée à chaque cas (soit les tourbières non drainées et drainées), on a dressé la liste d'un certain nombre de facteurs (15) (techniques, économiques, environnementaux, etc.) et on a attribué une pondération numérique pour indiquer l'importance relative de chacun lors du choix d'une méthode d'exploitation. Pour chaque méthode, on a ensuite attribué une cote à chaque facteur en vue de classer les méthodes. La méthode avec la cote la plus élevée faisait ensuite l'objet d'une étude économique plus poussée.

Dans le cas des tourbières non drainées, la méthode choisie de la façon décrite ci-dessus a été l'excavation en vrac au moyen d'une drague amphibie. Dans le cas des tourbières drainées, c'est le système de dragage avec pompage de la tourbe en suspension qui s'est le mieux classé.

8. Dans le cas de l'exploitation par voie humide des tourbières non drainées, l'excavation en vrac au moyen d'une drague amphibie a présenté, semble-t-il, certains avantages techniques bien précis, liés essentiellement à la souplesse et à la maniabilité de la drague amphibie. Il s'agit d'une machine autopropulsée (qui se déplace comme une tortue), n'exigeant qu'une faible profondeur d'eau pour se déplacer. (Aucune inondation importante au préalable de la surface de la tourbière). Le modèle actuel possède une pelle rétrocaveuse pour effectuer l'excavation, ce qui tend à limiter le rendement.

9. L'exploitation de la tourbe humide des tourbières drainées (ou partiellement drainées) au moyen d'une drague aspirant la tourbe en suspension représente une tentative de réunir les deux éléments clés de la méthode précédente d'exploitation de la tourbe hydratée (les "hydro monitors" et la pompe pour la tourbe en suspension), de modifier et d'améliorer le matériel et de l'utiliser simultanément avec la technologie nord-américaine en vue d'obtenir un système d'exploitation à haut rendement. On savait que les "hydro monitors" étaient efficaces pour la tourbe et que la pompe spécialement conçue pour la tourbe en suspension pouvait donner des caractéristiques satisfaisantes permettant d'obtenir des conditions optimales de pompage. Il a fallu trouver une embarcation susceptible de fonctionner dans des conditions de tirant

minimal (p. ex. grande drague amphibie ou barge sur coussin d'air) pour maintenir la teneur en solides requise et fonctionner sur une tourbière drainée ou partiellement drainée.

10. Pour obtenir des conditions optimales de pompage de la tourbe en suspension (p. ex. capacité maximale de pompage, distance maximale de pompage, diamètre minimal des canalisations), on tient compte de facteurs comme la teneur en solides, la viscosité, le débit et les pertes de pression. Il est possible de déterminer ces paramètres en utilisant les données et les méthodes de calcul relatives au pompage de la tourbe en suspension, mises au point précédemment en URSS. Il faut obtenir un certain degré de corrélation entre les systèmes de saisie de données employés en Europe et au Canada et la mise au point de nouvelles méthodes de laboratoire, pour tirer profit des données européennes actuelles sur le pompage de la tourbe en suspension.
11. Dans le cas des opérations actuelles d'exploitation de la tourbe humide, on recommande de fabriquer pour la tourbe en suspension une pompe spéciale susceptible de posséder des caractéristiques de préparation de la tourbe de haute qualité (soit broyage, coupe et mélange suffisants) et permettant aussi de pomper la suspension sur une distance maximale.
12. On a calculé les coûts d'utilisation des deux méthodes d'exploitation convenant le mieux aux tourbières non drainées et drainées. On a calculé un coût unitaire uniforme (y compris les coûts d'investissement et d'exploitation) pour l'excavation de la tourbe en vrac au moyen d'une drague amphibie (utilisée pour une tourbière non drainée); ce coût est de 30,20 \$/tonne (pour une teneur en humidité de 50 p. cent). De la même façon, on a calculé un coût unitaire uniforme de 6,68 \$/tonne pour la méthode utilisant une drague avec pompage de la tourbe en suspension (pour une teneur en humidité de 50 p. cent). La production annuelle s'est chiffrée, dans les deux cas, à 50 000 tonnes et à 250 000 tonnes de tourbe séchée à l'air (pour une teneur en humidité de 50 p. cent), respectivement.
13. Même si l'exploitation d'une tourbière non drainée ne requiert préalablement que peu de préparation ou de drainage en surface, notamment par rapport aux méthodes d'exploitation par voie sèche, on a constaté que le matériel nécessaire à ce type d'exploitation (excavation de la tourbe en vrac par drague amphibie) entraînait des coûts d'investissement relativement élevés par unité de capacité installée, en comparaison du système choisi pour exploiter une tourbière drainée (drague aspirant la tourbe

en suspension). La méthode d'excavation de la tourbe en vrac, qui a été sélectionnée, avait également, semble-t-il, une capacité trop faible et exigeait les mêmes ressources en main-d'oeuvre que la méthode utilisant une drague aspirant la bourbe en suspension, dont la production était plus élevée. La souplesse d'utilisation et la maniabilité de la drague amphibie à la surface des tourbières en donnent une impression favorable; c'est pourquoi une étude plus poussée de la méthode d'exploitation par voie humide utilisant cet équipement est probablement justifiée.

14. Une comparaison des facteurs économiques et techniques a fait ressortir certains avantages de l'exploitation par voie humide: p. ex., augmentation de la capacité unitaire, augmentation du rendement par mètre cube de tourbe brute, diminution des exigences de superficie active et main-d'oeuvre moins importante. Cependant, si on compare avec la méthode utilisant de la tourbe broyée (méthode par voie sèche), les exigences énergétiques totales pour 1 000 tonnes de tourbe séchée à l'air sont plus élevées pour les méthodes d'exploitation par voie humide.
15. Le cadre de la présente étude n'a pas permis d'approfondir le domaine du pompage de la tourbe en suspension. On recommande d'entreprendre des recherches plus poussées sur la rhéologie de la tourbe en suspension et d'utiliser les données considérables accumulées en Europe pour vérifier les hypothèses et les résultats présentés dans le présent rapport.

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PART 1

REVIEW OF AVAILABLE INFORMATION ON
WET PEAT MINING SYSTEMS IN USE

PART 1 - REVIEW OF AVAILABLE INFORMATION ON
WET PEAT MINING SYSTEMS IN USE

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1.0 REVIEW OF AVAILABLE INFORMATION ON WET PEAT MINING SYSTEMS IN USE

1.1 WET PEAT MINING SYSTEMS FOR UNDRAINED BOGS

111 HYDRAULIC CUTTERHEAD SUCTION DREDGES

Two interesting and comprehensive reports were issued during 1982 highlighting the use of cutterhead suction dredges for the production of peat for energy purposes. One in Canada carried out for the National Research Council by Kesmark Limited (Morris, 1982) was completed in March 1982 and another report was issued in July, 1982 in the U.S.A. by the Gas Research Institute (Punwani, Aspinall, Lofton, 1982) in Chicago, Illinois on work done by the Dravo Corporation. Since it was specifically beyond the scope of the current investigation to study cutterhead suction dredging technology (which is amply described in the aforementioned reports), remarks herein will be confined to a brief comparison on certain key findings of the two documents.

A noticeable point in both studies is the treatment of the subject of pumping peat slurries. The Dravo study considered production of 8.6 million dry tonnes (9.5 million dry tons) per year of fuel peat production as feedstock to a gasification plant. The largest portable dredge currently made in the U.S.A. was selected as the base machine and a 1,220 mm (48 inch) diameter pipeline and a 915 mm (36 inch) series 5000 dredge pump (15,900 cubic meters/h or 70,000 USGPM) was selected as being most economical. The Kesmark investigation reported on dredging estimates for three Ontario locations ranging from about 635,000 dry tonnes (700,000 dry tons) to 1.5 million dry tonnes (1.65 million dry tons) per year of fuel peat and considered 405 mm (16 inch) and 610 mm (24 inch) cutter-suction dredges.

The following excerpts are from the Dravo report:

"One major problem encountered in the slurry pond harvesting system design has been the lack of information on the slurry pumping characteristics for peat. Considerable time was spent researching literature on this subject without success."

"The pumping characteristic of the dredged peat is one of the most important factors affecting the harvesting system design. The importance of detailed pumping characteristics cannot be over stressed since pumping characteristics determine head losses, flow quantity, the number of pumps required, the number of dredges required and horsepower on the pumps."

"A literature search seemed to demonstrate that peat slurries are non-Newtonian and that none of the proper laws or Bingham plastic models are appropriate. Previous research shows that friction factor versus Reynolds number varies with concentration and pipe diameter, so full scale tests will probably be required."

"The two percent slurry concentration was selected as the most likely and optimum to be produced by the dredges. The reasonableness of this assumption will be open to question until actual field tests are made, however:

- o Costain-Blankevoort International Dredging Company Limited removed 30 to 40 feet of peat from above a coal deposit in the United Kingdom with a 26 inch hydraulic cutterhead dredge to a rate of 870 to 900 cubic yards per hour. The 26 inch dredge pumped 20,700 gallons per minute. Assuming 200 tons of dry peat per acre-foot, the slurry concentration would be about 2.1 percent.

- o Western Peat Moss in Vancouver, Canada, pump horticultural peat from a floating clamshell dredge in a 0.75 to 1.5 percent by weight slurry. In addition, Mr. Charles Carncross, Vice-President, Western Peat Moss Company, reported:

"My attitude is that the slurry should be relatively thin (up to 2%) for conveying in pipelines over long distances to keep the pressure drop and power requirements to a minimum".

- o According to R. Vanasse, B. Coupal and M.I. Bovlos (Chemical Engineering Department, University of Sherbrooke, Sherbrooke, Quebec) for peat moss:

"At an average slurry velocity of 1.0 meter per second, the pressure drop per unit length of pipe increased by almost one order of magnitude with the increase in concentration from 2.75 to 3.5%."

"The peat slurry concentration could be varied during harvesting by changing the dredge cutting rate. To determine the economics of varying the system to pump a thicker slurry, a method for estimating friction losses was developed. For lack of better information, paper pulp data reported by Cameron Hydraulic Data, Goulds Pump Manual, and the Hydraulic Institute Data Book was used as a basis for developing head losses."

"Results extrapolated for the 48 inch pipe from water and slurry curves showed that a two percent slurry would have pumping characteristics similar to water, but that a three percent slurry would have considerably higher head losses."

"The effects of slurry concentration have been explained in previous sections. In summary:

- o Dilute peat slurry concentrations (two percent peat by weight or less), probably pump similarly to water. Therefore, increasing the slurry concentration in a pipeline up to some rheologically defined inflection point would increase production with pumping costs remaining about the same. For instance, increasing a slurry concentration from 3/4 percent to 1.5 percent may double production from the same pumping equipment for about the same costs.
- o At slurry concentrations above this rheologically defined inflection point, pumping costs are very sensitive to small changes in slurry concentration.
- o The exact slurry concentration at which the inflection point occurs will depend on the specific properties of a particular peat, however we estimate that it will probably occur at a slurry concentration somewhere around 2 percent peat by weight."

Dravo selected the 915 mm (36 inch) centrifugal dredge pumps (with 5500 h.p. motors) because they were the largest capacity dredge pumps available in the USA and discussed certain modifications to the units to improve performance in peat. They added a further comment regarding peat slurry pumps:

"Specially designed and built pumps may be better suited for pumping peat, but such design was beyond the scope of this project."

In contrast to the Dravo approach, the Kesmark study considered that peat was pumpable at 10% solids by weight. This conclusion appears to be based on the dredging contractor's experience on removal of various materials including certain amounts of peat at various locations in Canada and also in Africa. Various reference projects were briefly described and included the removal of 11.5 million cubic meters of overburden materials consisting of sand, clay, gravel and 1.5 million cubic meters of peat from a potential mining location in northern Manitoba. A Quebec City project was referred to where dredging of silt and bark from the river bottom yielded a slurry which extruded and had the appearance of toothpaste. Experience was also cited on the use of dredges to remove mangrove peat and trees at a location in Nigeria, Africa. Further, the following excerpts from the Kesmark report outlined their reasoning:

"Peat slurry percentages pumpable:

Both Fisons-Western Peat Corporation and Dravo Corporation consider that peat slurries exceeding 3% peat by weight are unpumpable. However, it must be remembered that the former is dealing with peat moss, which differs markedly from the fuel peat considered in this study. In addition, they wash much of the fines away before pumping.

The various operators who use cutter-suction dredges are of quite another opinion and generally believe that in-situ peat of 10% solids can be pumped, after maceration with a bladed cutter-head. For the purposes of this study, it is considered that the dredge cutter suction action cannot be constantly maintained at the peat face and this will cause 25% water to be added, to produce a slurry of 7% to 8% by weight.

There is a further caution for those selecting peat deposits to be dredged. A 95% water in-situ peat (by weight) has double the water content of a 90% deposit. Thus the dredge, in pumping equal volumes, would move only half as much peat at 95% and costs would approximately double per unit of peat.

Dredge operators have no actual proof of their assertions on pumpable slurries, as peat is usually excavated in association with other mineral soils. Were a field experiment to be carried out to prove this matter, it is believed that it could only be performed at full-scale in the field. A dredge to be so employed would require substantial alteration to perform in peat. Such a test would require considerable pre-planning and should address all aspects of peat dredging that might be in question for a specific site."

In the two previously mentioned North American studies on large scale peat dredging, it is obvious there existed an almost total lack of information on the rheology of peat and the pumping characteristics of peat slurries. A search of the generally available literature for the current work also revealed very little published material on the subject. Fortunately, in the preparation of this report, Monenco had access to information on wet peat mining technology and peat slurry rheology and pumping characteristics from the considerable experience in the USSR, where wet peat mining and peat slurry pumping was practised for nearly fifty years on a large industrial scale.

1.2 WET PEAT MINING SYSTEMS USED FOR DRAINED BOGS

121 INTRODUCTION

The following paragraphs describe a number of wet peat mining methods used on drained peatlands in various countries of Europe and in Canada including the bucket excavator (Bagger system) method, the hydropeat (slurry ditch) method, and also the small scale hydropeat method.

Although commonly thought of as a dry mining technique, the bucket excavator (Bagger) method has been included as a potential wet mining method since the mining part of the method (excluding the drying operation) is a wet mining technique which involves the excavation of raw peat from drained peatlands and a certain amount of "processing" which occurs on the Bagger equipment. The "processing" consists of cutting, macerating and extrusion of the peat and is expected to produce a good quality feedstock for the process plant (i.e. high solids content, about 12-15% by weight, and a well mixed and macerated peat product).

A number of figures have been included from European sources. The authors attempted to obtain good quality reproductions but this was not always possible, in particular with certain of the Soviet publications.

122 BUCKET EXCAVATOR (BAGGER) METHOD

.1 The Federal Republic of Germany

Statistics given by the Hanover Institute of Peat after the Second World War, showed that the yearly peat production was about 300,000 tonnes of sod peat which was used for various manufacturing processes and also for electrical power generation. At present, the use of peat as a fuel has virtually terminated due to depletion of the resources and for land management reasons.

Typically, peat bogs exploited for fuel peat were raised bogs with a degree of decomposition 20-25%, (see Part 231 for discussion on degree of decomposition terminology used in this report), about 4 m in depth and without stumps wooded areas. The first step in mining was to remove the top sphagnum layer and prepare the production fields for subsequent fuel peat mining. Figure 1-1 shows the "Wielandt Bagger" bucket excavator commonly used with a peat conveyor which spread the peat sods up to 54 m across the field. The width of the bagger bucket was about 2 - 2.8 m wide. The "Bagger" equipment was exported to Ireland and other countries where similar systems were developed.

As mined, the raw peat was fed to a screw extruder and was processed and fed through a mouthpiece to a feeder conveyor. Attached to the Bagger machine was a spreader which filled with peat over its full length and spread the peat to dry over the drying field. A cutting wheel with many disks cut the long strips of peat into blocks or sods. The weight of the Bagger equipment with conveyor was about 50 tonnes, and had a capacity of about 100 cubic meters/h of raw peat. The working travel speed was from 18 to 30 m/h and the equipment had an electrical power requirement of 80 KW.

Bagger equipment (Wielandt) was used only on large mining fields. For small or average size mining fields the "Lilliput" and "Miniput" Baggers were also manufactured. The "Lilliput" Bagger (Figure 1-2) worked on stump-free deposits. The capacity of the machine was from 60 to 80 cubic meters/h (8-10 tonnes/h air-dried peat). A diesel engine of 60-100 h.p. was required. The bucket frame could be changed to different positions and varied in depth without stopping. The weight of the machine was 14 tonnes. The working width of the bucket frame was 1.05 m. Maximum depth of peat excavated was 3.5 m and length of the spreader conveyor was 20-30 m. The machine had a low bearing pressure and could be used on wet fields. This Bagger was also used to dig ditches to drain wet peatlands.

The "Miniput" bagger was a lighter machine with accessory equipment and was used not only for mining peat but also for field levelling. The weight of the "Miniput" machine was 8 tonnes and excavated to a depth of 3 m. The width of the bucket frame was 0.48 m. The working travel speed was 36 m/h with a power requirement of 40-75 h.p. Two operators were required.

To cut peat with a low degree of decomposition (e.g. sphagnum top layer), a machine called the "Steba" (Figure 1-3) was used. It had tracks for travel, powered by a 10 h.p. diesel motor. This equipment worked only on stump free fields and had a capacity of up to 75 cubic meters/h. The block peat measured 15 cm x 15 cm x 40 cm. The machine weighed about 4 tonnes and required one operator. The cutting was done vertically through the deposit cutting 10 blocks at once (e.g. 2 rows, 5 blocks); the blocks were removed from the pit and were stacked on the edge of the cut. The same kind of machine has been used at a New Brunswick peat operation in recent years.

.2 Ireland

Ireland has a number of thermal power stations fired on milled and sod peat which generate about 580 MW of power or nearly 40% of the electrical power in the country. The mining of sod peat is done mainly by a large tracked Bagger, weighing about 45 tonnes. The capacity of the machine is up to 140 cubic meters/h and production is about 25,000-30,000 tonnes per season (air dried, 35% moisture content) per machine. The Bagger is electrically driven fed by a trailing flexible cable. The cutting action of the buckets provides a good mix of the light quality top peat with the more highly humified bottom peat. The buckets discharge into a conveyor which feeds the peat to the macerator. The macerator is the 'kernel' of the Bagger and consists of a casing which houses twin counter shafts revolving at 182 rpm, each carrying an assembly of transport screws and mixer blades which mix, macerate and extrude the peat onto the spreader.

The light surface layer of peat is initially removed with an auger machine and placed into the pit. The width of the cut is 2.4 m. The weight of the machine is 8 tonnes, and it has a capacity of up to 160 cubic meters/h. The smaller German bagger machine is also used for mining (see Figure 1-4). Recent information indicates that the larger electric machines are becoming obsolete and the Lilliput-type machine manufactured in Ireland is most common. The capacity of the Irish machine is 90 cubic meters/h.

After the peat is spread on the fields to dry, it is windrowed and turned for further drying, finally collected and placed in stockpiles. Sod peat is then loaded as required into railcars for transport to the power stations. The cars are 16 cu.m. capacity and hauled by 35 to 60 kw diesel locomotives on narrow guage rail.

.3 The U.S.S.R.

Before the 1920's, typically, peat was excavated from pits by hand (see Figure 1-5) and placed on an elevating device for transport to the top of the pit where the peat was pressed and loaded into small railcars for transport (again manually) to the forming and drying areas. In 1921, a four chain bucket elevator arrangement was adapted on the frame of the elevator machine. The cut face width was 1.9 m and the machine had to move along the edge of the pit (Figure 1-6). This equipment was called a "Pankratov Bagger" bucket excavator and was used only where there were no stumps.

In 1926, a new Bagger was built (based on the elevator model) called a "Birukov Bagger" (Figure 1-7). A five chain frame was attached which doubled the excavating width to 4.3 m. In 1927, the Peat Institute devised a cable conveyor which mechanized the transport of the formed peat to the drying field, and in 1928 a four row bagger with a bucket chain frame was developed (see Figure 1-8). The excavating buckets were inclined at 30% to the horizontal, which prevented collapse of the excavated face. The peat was excavated to a depth of 4 m maximum with a cut width of also 4 m. This Bagger could operate on a peat bog with a stumps content of up to 1%. Working 2 shifts per day, the machine could produce about 12,000 tonnes of air dried peat annually.

In 1936 the sod spreader was developed (Figure 1-9), which transported and spread the extruded peat on the fields to dry. The introduction of the spreading machines greatly mechanized the mining of peat. In 1949, the Peat Research Institute developed a peat excavator (Bagger) capable of mining peat to varying depths. It worked with 2 or 3 diesel or electric spreading machines (Figure 1-10). The maximum depth of excavation was 4.25 m and the width of cut was 12.5 m and the machine was capable of handling peat with a high stumps content. Total weight was 44.5 tonnes with an average bearing pressure on the bog of 0.25 kg/sq.cm. The sod spreaders loaded with peat had an average bearing pressure of about 0.33 kg/sq.cm., and a track width of about 0.9 m.

The Peat Research Institute Bagger, working with a spreading machine, claimed to have the following characteristics:

- ability to vary the mining width (average width 12.5 m),
- could operate in shallow peat deposits,
- could operate in peat bogs with up to 3% stumps, and separated out stumps and roots,
- minimized the collapse of the peat face during mining,
- had the ability to spread peat sods in all sizes and shapes, and
- the peat bog could be mined throughout the total depth and as a result produced a high quality peat product.

Currently, sod production in the USSR is about 5 million tonnes annually or about 5% of the total industrial peat production. The main use of sods is for public heating systems and they are also used as a domestic fuel. Generally, there has been a growth in production.

The use of this method in the USSR began in 1914 and by 1920 the production of peat by the hydropeat method was about 6,000 tonnes (air-dried peat). In 1950 a maximum production of 9.8 million tonnes (air-dried) was achieved. The hydropeat method was used exclusively in bogs where there were stumps in the top layer. The number of people employed in hydropeat operations decreased from 21,000 people required to mine 1 million tonnes in 1928, to 4,500 men to mine the same tonnage in 1940.

The main function of the hydropeat mining method was to produce a peat slurry, using a powerful jet of water and transporting the peat slurry by pumping to drying fields where a fuel peat product was prepared. The water jet (Figure 1-11) loosened the peat layers and converted the raw peat to slurry form with a solids content, in lowmoor peat bogs, of 4.5% and about 3.5% in highmoor bogs (see also Part 231 for a discussion of peat type terminology as used in this report). It was possible to prepare a pumpable peat slurry without undue concern about stumps content. The hydromass was pumped from the open pit (Figure 1-12), with the aid of the peat slurry suction pump (a centrifugal-type pump). Another type of centrifugal pump transported the peat slurry from transit reservoirs by pipeline the desired distance from the bog. It was economical to transport the hydromass for a long distance, sometimes up to 30 km.

In the USSR, hydropeat mining was performed by two types (sets) of machinery - new standard (N.S.) (Figures 1-13 and 1-14) and super standard (S.S.) (Figure 1-15). Either set of machinery included equipment which performed the dilution of the raw peat by high pressure water jet, removal of stumps from the peat slurry path, pumping of the peat slurry by a special peat slurry pump through a pipeline to slurry collecting reservoirs which accumulated the slurry from several equipment sets for further pipeline transport to either transit reservoirs or to the drying fields. Individual sets of machinery were grouped into no more than five for the N.S. and no more than two for the S.S. The number of sets depended on the amount of peat to be mined in one season. Each group had a period of mining in one area where it stayed for the duration of the operation. Each set was assigned to its own field (seasonal pit) for the season, which was determined by the seasonal mining program - evenly distributed to ensure full equipment utilization. Each seasonal pit was divided into smaller working pits where a set of machinery remained stationary until the peat reserves were exhausted (see Figure 1-16). The capacity of the peat slurry pump used in the working pit was 500-600 cubic meters/h of peat slurry for the N.S. set and the seasonal output of a single set of N.S. equipment was about 50,000 tonnes air-dried peat at 35% moisture content.

The slurry crane (Figure 1-16) was located on the edge of the working pit mounted on a 45 m section of movable rail track. The high pressure water pump station (position 12) was located above a pumping pit (position 11) 65 m from the edge of the working pit and travelled on the temporary rail track (13). The pumping pit (Figure 1-17) supplied water for 2-3 working pits. From the pumping station, the water was pumped through a network of pipelines which were periodically relocated in the pit working area. The pipelines were connected to the hydromonitors (position 20) and out of 4 hydromonitors, two were in operation on every N.S. equipment set, and two were being prepared for future work.

An overall view of the working pit area of the N.S. machinery set is shown in a step by step sequence in Figure 1-18. Figure 1-19 shows the details of the hydromonitor.

The Peat Mining Operation Rules determined the following working pit sizes:

- a) For N.S., 125 x 45 m on peatlands where there was no risk of collapse.
- b) For S.S. equipment, 200 x 60m.

Where the width of the seasonal pit was 125 m (N.S.) and 200 m (S.S.), the length of the seasonal pit was dictated by the peatland depth and the seasonal capacity of the peat mining machinery. Usually the centre line of the rail crane divided the seasonal pit into two equal parts. If the maximum depth of the pit was located eccentrically, the 1-20 centre line was shifted in that direction by an appropriate amount (10-15 m). Figure 1-20 shows groups of N.S. equipment sets excavating peat and pumping peat slurry to a common collecting reservoir for further pumping.

Figure 1-21 shows the general arrangement of the Super Standard equipment set operating in a working pit. The rail crane (position 1) was located on the rail track on the edge of the working pit. Both movable water pumping stations (position 5) were located 15 m from the edge of the working pit. The movable water supply main was located on the narrow-gauge pumping station rail track. When there was a high risk of working pit face failure the set up was changed and the second pumping station was then located 75 m from the edge of the working pit. Every pumping station had 120 m of movable rail track and the track was installed in advance of the cranes. Two excavators (position 7) were used to clear the path for the peat slurry.

The Super Standard (S.S.) equipment set was used when a higher output was required (e.g. about 190,000 tonnes of air-dried peat, 35% moisture content, per year per equipment set) than available from the N.S. equipment. The capacity of the peat slurry pump used in the working pit was 1,000-2,000 cubic meters/h of peat slurry. The configuration of the peatlands had to be amenable to the operation of the equipment sets.

On shallow peatlands (2-2.5 m) and on well drained peatlands, the N.S. crane was mounted on rail tracks without foundation piles. On deep peatlands, piling was required (see Figure 1-22). The weight of the N.S. crane was 28 tonnes; the S.S. crane was 38 tonnes. The number of piles (when required) under the N.S. crane was not less than 8 and under the S.S. crane not less than 12. The S.S. equipment was always used with pilings.

Figure 1-23 shows a standard transit slurry reservoir with a capacity of 1500 cubic meters. They were usually excavated to a maximum depth of 1.5 m. at a 5 cm per 100 m incline towards the pumping station. Local soils were used to form the containment berm which was up to 2-2.5 m high. The maximum height of the berm was located at the pumping station to protect it from damage from overflow of the peat slurry.

A peat slurry (sewage-type) pump was used to pump the peat slurry from the transit reservoir. Low capacity peat slurry pumps were originally used (500 cubic meters/h with discharge pressure of 23.5 m). The pumps were considered to be of high pressure construction and the suction head had a propeller to repel debris. However, experience showed that the peat slurry being pumped from the slurry reservoir was without roots or other debris and therefore the special propeller form and cutterhead was discontinued. A standard (sewage-style) peat slurry pump was in later years on slurry reservoirs with a pump capacity of 1450 cubic meters/h at a pressure of 24 m water column. The peat slurry transit pipeline used from one slurry reservoir to another was made from standard metal pipe of sizes 755, 680 and 570 mm.

Water for the hydromonitors was supplied from adjacent streams or lakes and pumped to an open channel network which was used to distribute the water by gravity to the various mining locations on the bog. The water lines were constructed from steel pipes or from wood, when gravity could be used.

A discussion on the methods used to dry and harvest the peat using the hydropeat method will not be included in this report since it is beyond the scope of work, and the methods are not recommended for the Canadian situation. The hydropeat slurry method was used in the USSR until the early 1960's and was discontinued in favour of the production of milled peat. Factors influencing that decision were:

- a) manpower requirements to move the various equipment components, many moves and physical changes, considerable manual labour for mining and drying and harvesting operations, etc. The system became uneconomical to operate since most of the operation was not mechanized.
- b) high equipment costs and metal costs for pipelines, etc., in general, the amount of metal required for the system, and the electrical power requirements, were excessive.

A small-scale version of the hydropeat method was used in Denmark from 1923 to the early 1950's. It has been described in a Geological Survey of Finland publication of 1949 by M. Salmi. The method was essentially the same as the hydropeat method used in the USSR but about 1/10 the scale of the New Standard equipment set.

The portion of the peat deposit to be mined each year was divided into 12m x 30m fields by shallow, open ditches. The peat was removed from each field without moving equipment around. The equipment set was composed of two hydromonitors and one peat slurry suction pump. The peat was loosened by the water jets (8-10 atmospheres water pressure, increased to 12-15 atmospheres under difficult conditions e.g. larger, woody remnants). Each hydromonitor required about 100 cubic meters/h of water.

The homogenized peat slurry was guided into a small collection basin from where it was pumped to a nearby storage reservoir by use of a special centrifugal peat slurry pump of 200 cubic meters/h capacity. The slurry pump cut, ground and macerated the peat slurry prior to pumping. From the storage reservoir, the peat was pumped to drying fields where the slurry was spread out and allowed to settle. After settling a few days, the peat was cut into blocks and left to dry in the sun and wind. Production was about 10,000 tonnes of air-dried peat per season. About 35 ha of drying fields were required and two harvest cycles were possible.

It was reported that an ample water supply was required (e.g. a pond or prepared water reservoir on the bog). Each cubic meter of peat removed was said to require an equal amount of water. The pumping required an economical electrical supply. Further, the method required large drying fields, and grass-covered sandy fields were best suited. Shallow parts of the peat deposit also could be used if the area was properly drained by mole drains.

Information based on the Danish experience showed that in order to avoid mixing clays and silt into the peat by the action of the water jets, the bog should have a flat, hard mineral soil base. The use of the small-scale Hydropeat method required a thorough survey of the peat thicknesses, base contours and peat type distribution.

A similar, small-scale version of the hydropeat method also had limited use in the USSR for peat mining, generally in peat deposits where there was an abundance of stumps. The mining technology was very similar to the New Standard equipment but the production rate was about one-third to one-quarter of the N.S. rate. A peat slurry pump with capacity of about 250-300 cubic meters, of a 3-4% solids concentration slurry per hour was used to pump the peat slurry about 1 km to an collecting reservoir. A crane (about 10 tonnes weight) was

used to suspend the slurry pump in the working pit and also as a mounting for the two water pumps supplying water to the hydromonitors. The working pit was 30 x 60 m. The hydromonitors had a maximum spray of 12 m and an effective radius of 3-4 m. The slurry pump had the same cutting, grinding and macerating characteristics of the N.S. and S.S. equipment.

125 AIR-CUSHION BARGE WITH CLAMSHELL

Since the 1930's, Fisons-Western Inc. has been using wet harvesting methods in its bog near Vancouver, B.C. The 2500 ha bog has peat deposits up to 3 m deep, consisting of sphagnum peat, mainly of von Post H3 and H4 classification. Drainage control is in place in the general area of mining activities and free water is not present on the surface. Current production is by air-cushion barge with an elevated hydraulic clamshell mounted on one end of the barge. The system has been the subject of much discussion over the past few years and has been described in a number of reports including a previous study by Monenco (1978). Perhaps the best description has been by Mr. Charles A. Carncross, Vice-President of Fisons-Western Inc. in the December, 1980 proceedings of the IGT conference on peat. Only a very brief description of the system will be included here for completeness.

Various wet mining systems have been utilized at the Fisons-Western operations in the past and a number were considered before selecting the air-cushion barge. The bog was described as being very soft and unable to support wheeled equipment like other bogs in central and eastern Canada. The bog also has a high content of stumps and tough, stringy roots. Based on years of experience, a barge was selected as the most appropriate equipment. However, even a barge experienced problems at this site since after peat was extracted, the surrounding peat tended to flow into the excavated area and "the bottom comes up". In two days it was reported that the depth of the working pond could be reduced from 3 m to 1.5 m and the barge was no longer floating. In a couple of weeks the bottom would come up another .5 to 1.0 m or so, so a shallow draft barge was not a solution.

Therefore, an air-cushion or hover barge system was selected. The barge in current use is 12 x 18 m and weighs 120 tonnes with slurry tank empty. The peat is excavated by a Cat 225 clamshell mounted in an elevated position on one end of the barge (Figure 1-24). The wet peat dug by clamshell is dropped into a small hopper and then onto a Rader screen. Jets of water at about 3.5 atmospheres pressure wash the peat from the roots and stumps which are discharged over the end of the barge into the pond. A separation is made on the Rader screen at about 7 mm, i.e. peat slurry and roots less than 7 mm in size go through the Rader screen into the slurry tank. The peat slurry in the

tank is between 3/4 and 1.5% solids by weight, and presents no problems in pumping, if the pump is designed to pass stringy roots. The roots have tended to ball and plug up in conventional centrifugal slurry pumps. The slurry is pumped through a 400 mm pipeline about 4.5 km long by a 8 x 6 x 17 L Wemco recessed impeller pump driven by a hydraulic motor. The peat slurry is then dewatered by an Ingersoll-Rand Vari-Nip press which reduces the moisture content to 75% for further processing. Final annual production is about 30,000 tonnes of 55% moisture content horticultural peat.

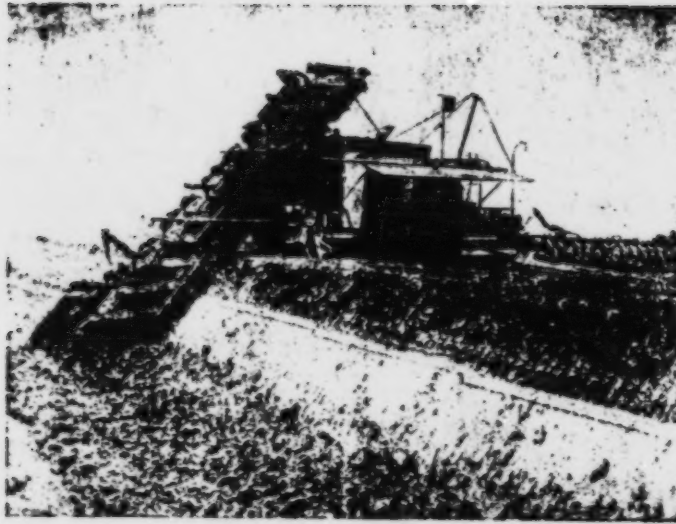


Figure 1-1 Wielandt Bagger Equipment

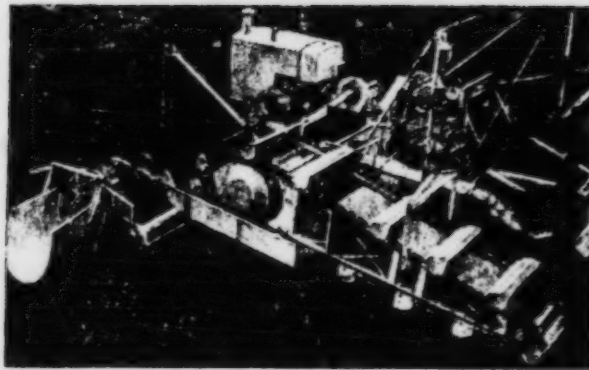


Figure 1-2 "Lilliput" Bagger Equipment

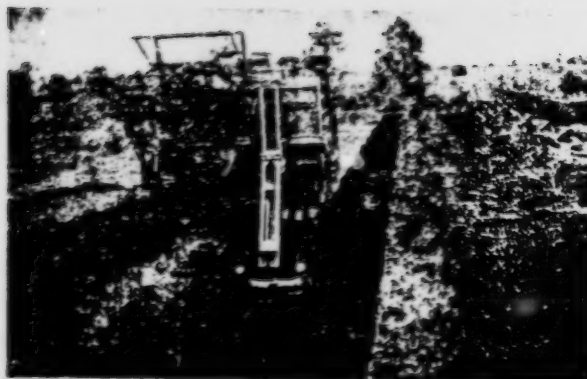


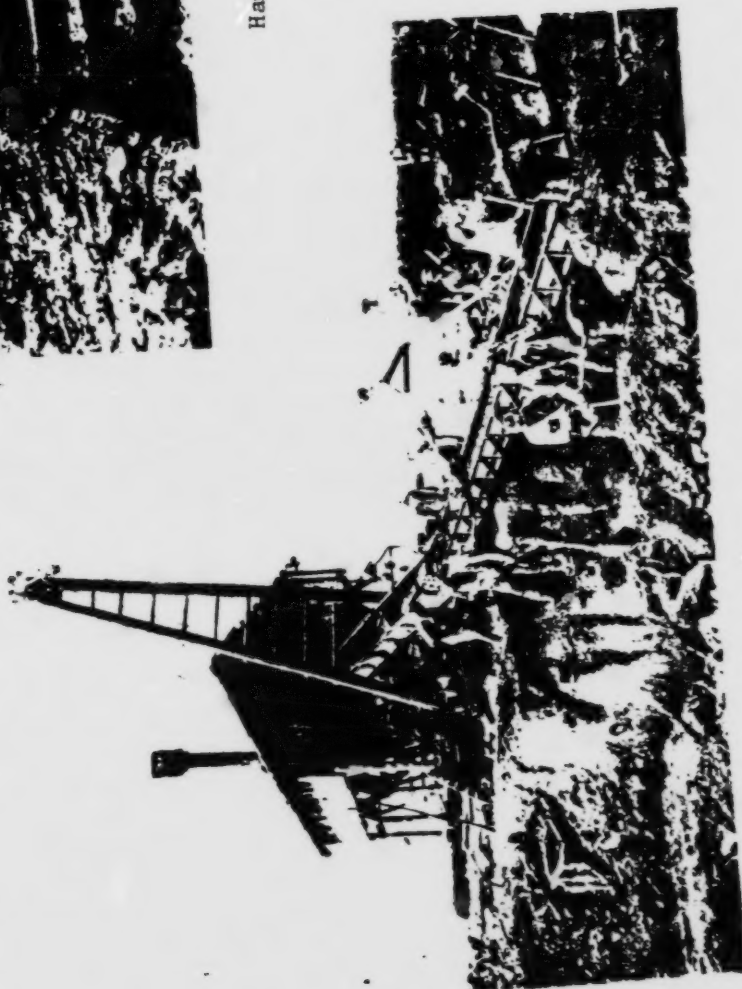
Figure 1-3 "Steba" Block Cutter Machine



FIG. 1-4



Handcutting Method of Mining
(low stumps content)



Handcutting with Bent Excavator
(higher stumps content)

Figure 1-5
Handcutting Methods of
Peat Mining

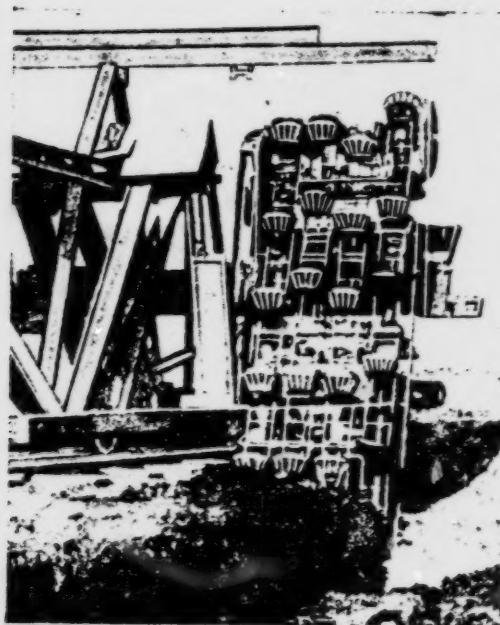


Figure 1-6 "Pankratov" Bagger

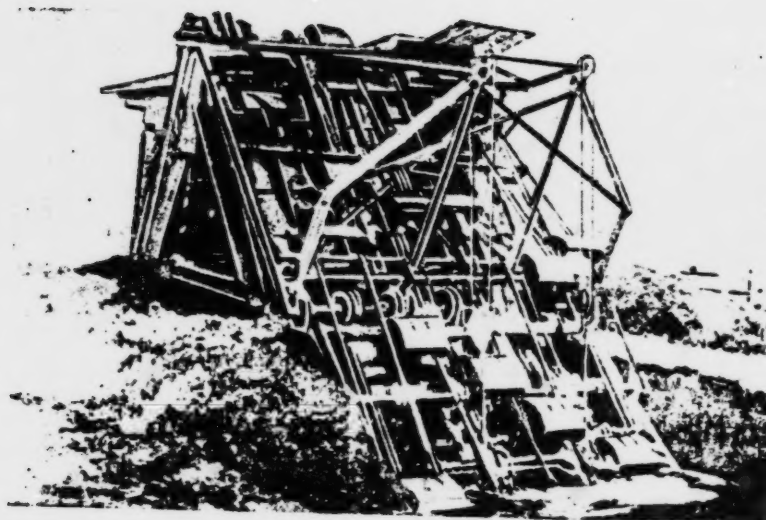


Figure 1-7 "Birukov" Bagger

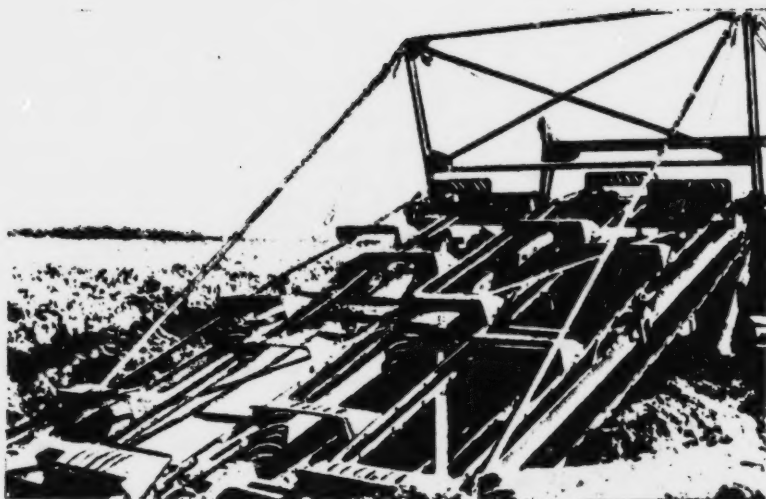


Figure 1-8 "Peat Institute" Bagger

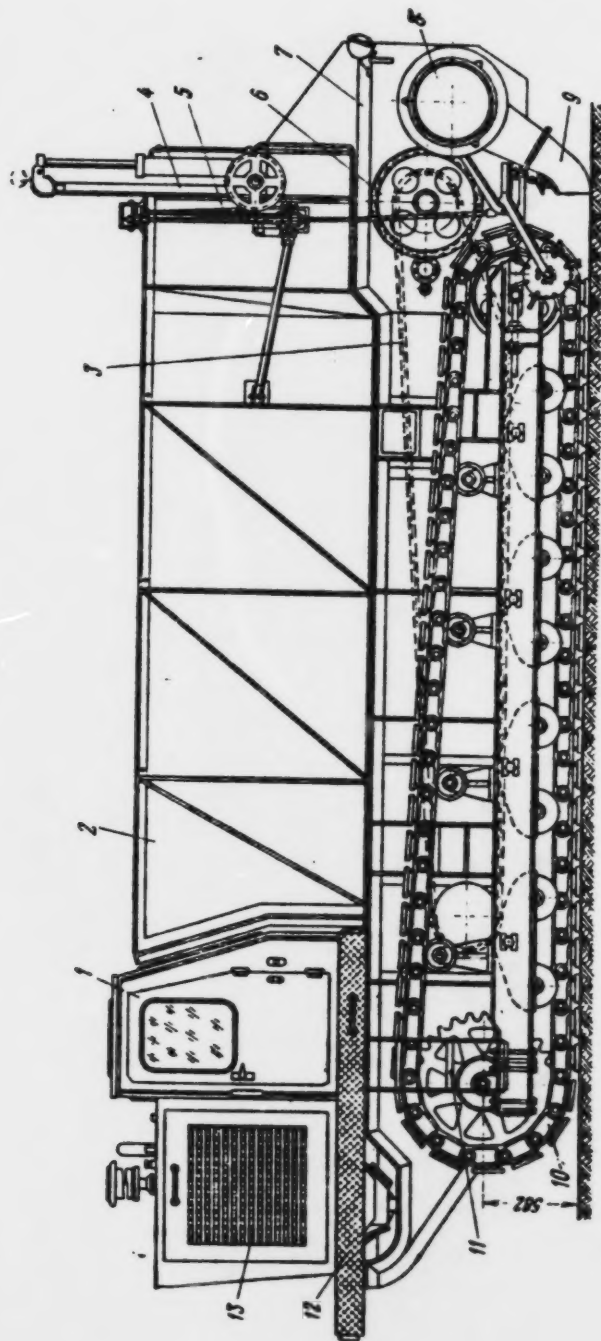


FIG. 1-9

NATIONAL RESEARCH COUNCIL

EVALUATION OF ALTERNATIVE
WET PEAT MINING SYSTEMS

DIESEL-POWERED SOD SPREADER

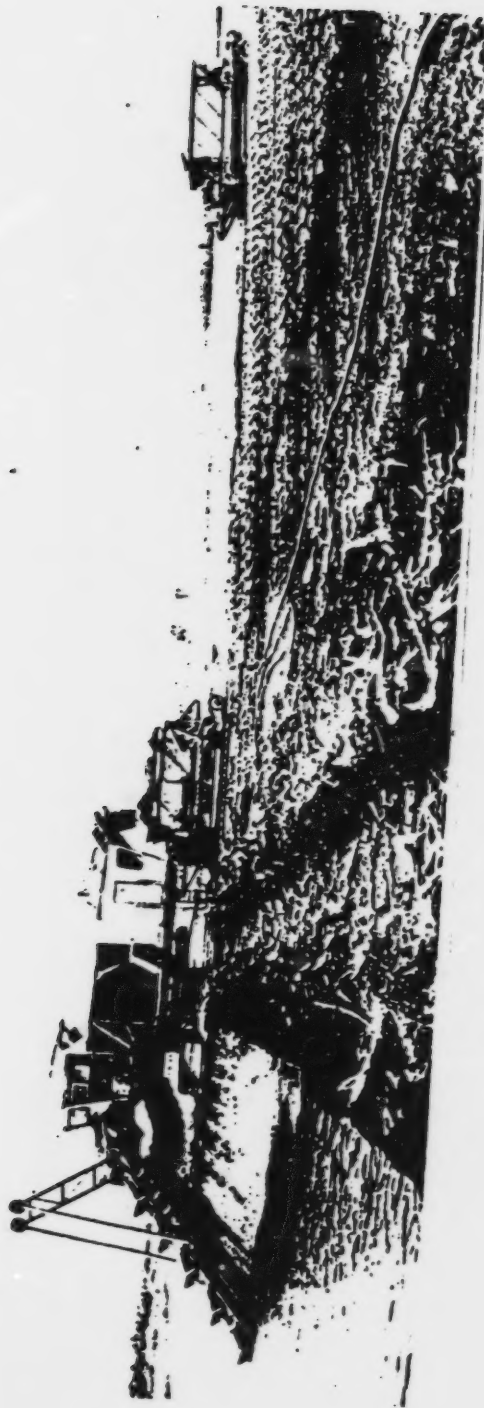


Figure 1-10 Variable Depth Bagger with Electric Spreaders

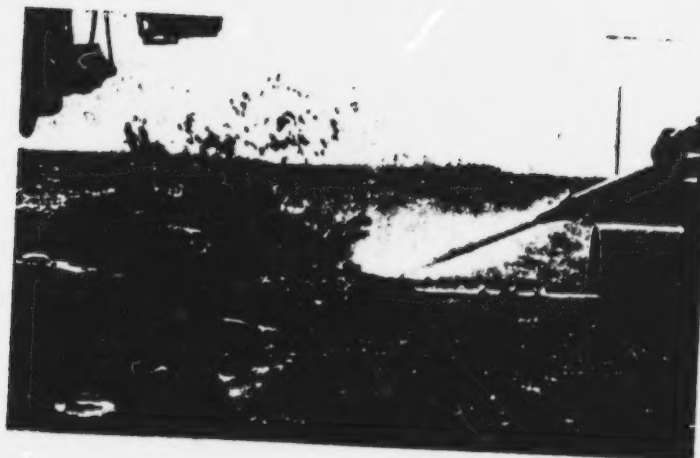


Figure 1-11 Hydromonitor Cuts Peat

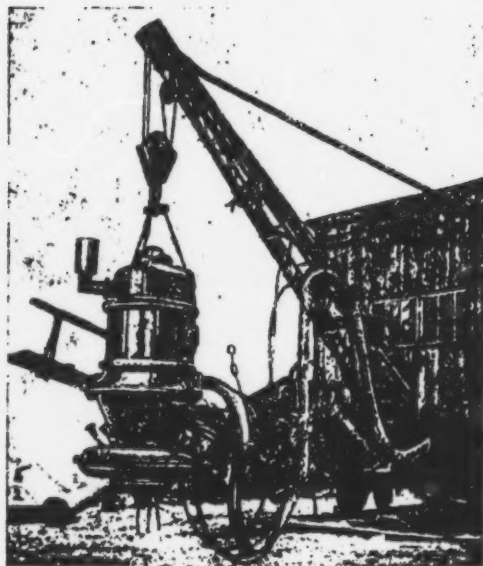
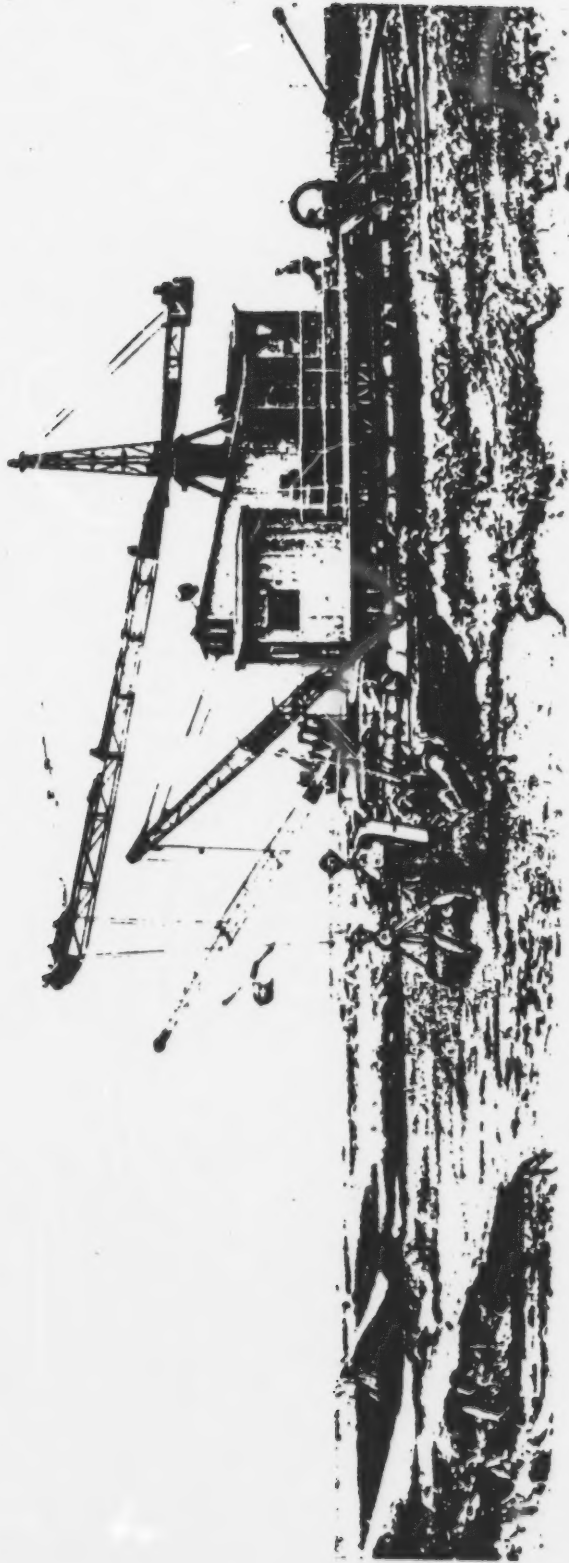


Figure 1-12 Peat Slurry
Suction Pump



The Set of Machinery for New Standard includes the following main equipment: Steel frame of the crane, drive mechanism for raising and lowering of the slurry suction pump, crane rail travel drive mechanism and auxiliary equipment; N.S. peat slurry suction pump; Crane boom with clamshell for the cleaning of the funnel of stumps and roots; High pressure water main for hydromonitors; Separate caterpillar excavator with crane boom with a special rake scraper for cleaning of the slurry path into funnel of stumps, roots and other undesirable debris; Peat slurry pipe line from crane to accumulator 570 mm; Electrical equipment.

Figure 1-13 New Standard Equipment Set

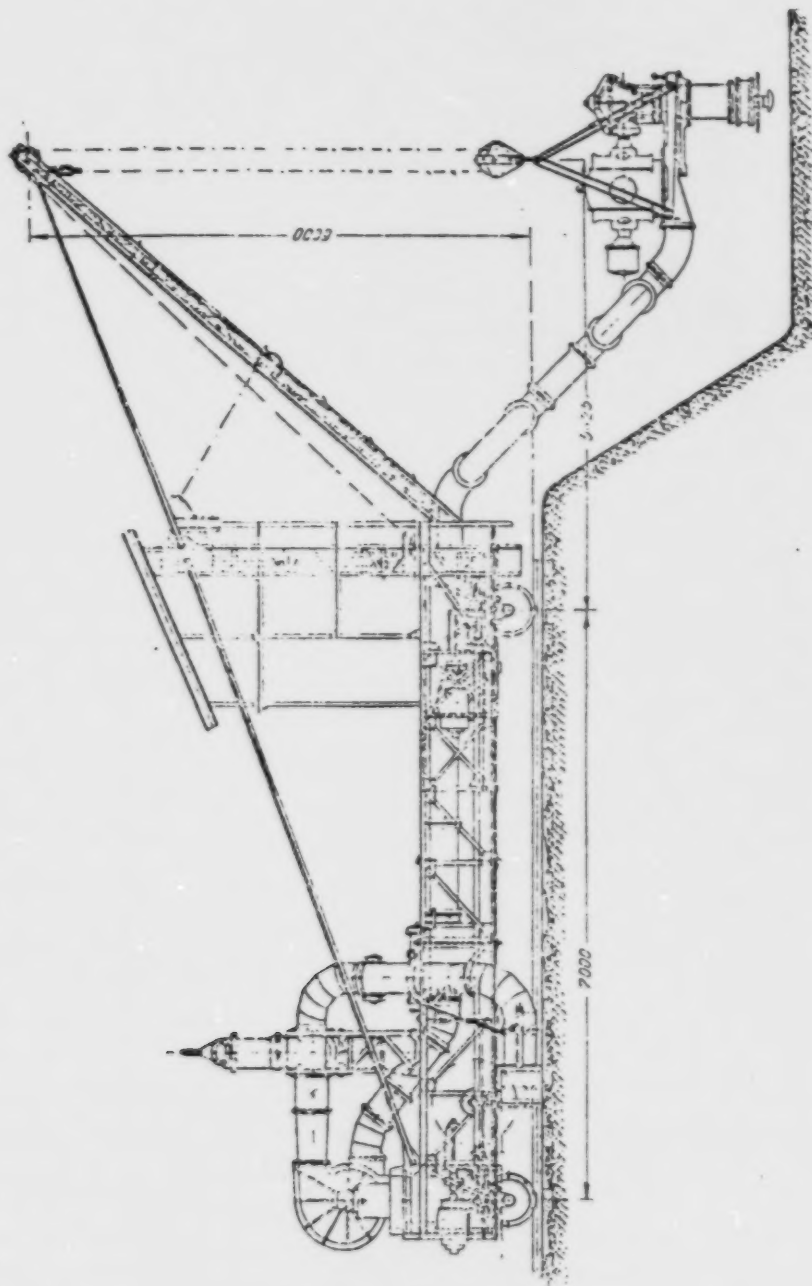


FIG. 1-14

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EVALUATION OF ALTERNATIVE

WET PEAT MINING SYSTEMS

NEW STANDARD MINING

PEAT SLURRY PUMP CRANE



monenco

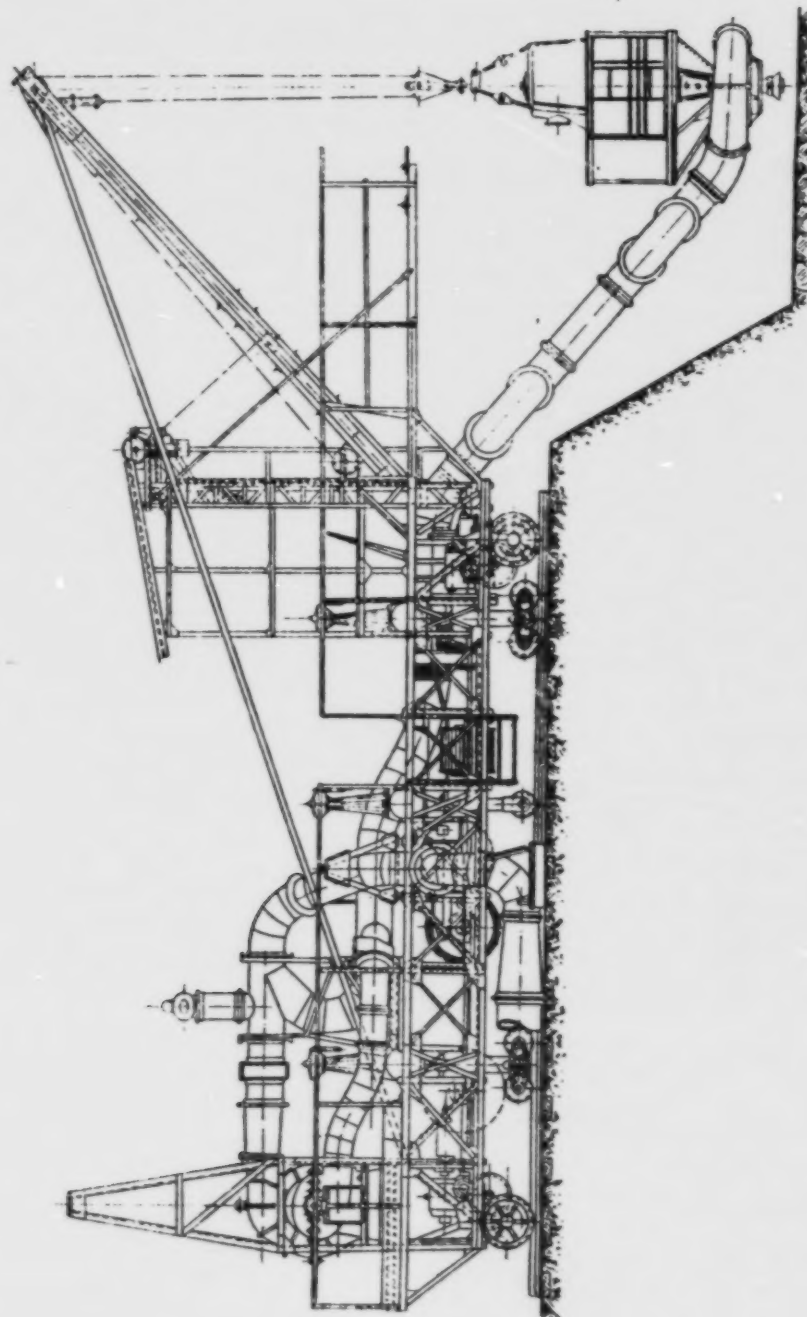
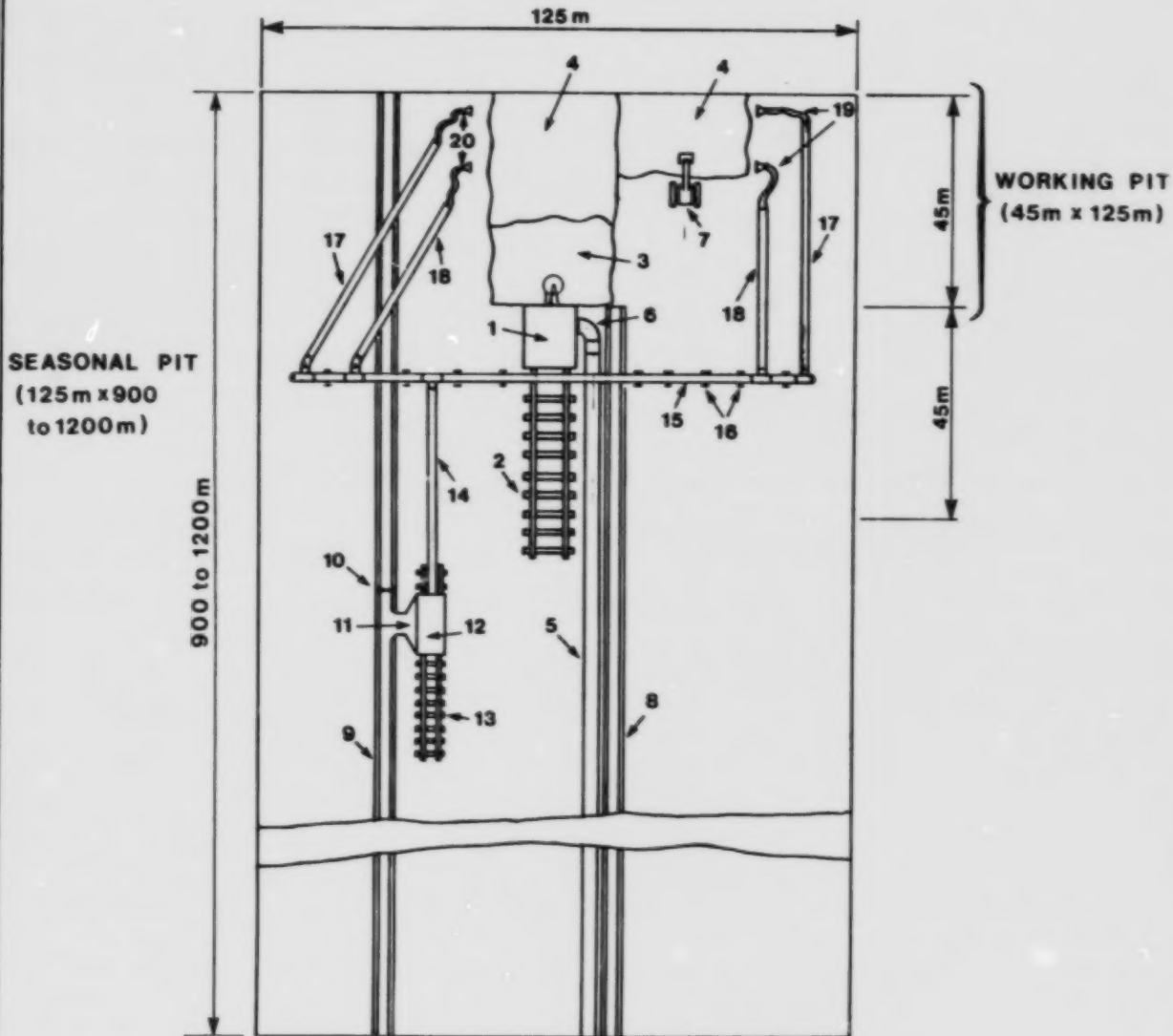


FIG. 1-15

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EVALUATION OF ALTERNATIVE
WET PEAT MINING SYSTEMS

**SUPER STANDARD MINING
PEAT SLURRY PUMP CRANE**



- 1 - Rail crane N.S. with peat slurry-pump and equipment for clearing stumps in open peat slurry funnel
- 2 - Rail track for crane
- 3 - Funnel 20 x 20 m.
- 4 - Trench 20 x 40 m.
- 5 - Crane slurry pipe-line 570 mm dia.
- 6 - Telescopic joint
- 7 - Excavator with extra long swing boom
- 8 - Open drainage ditch
- 9 - Open water tributary ditch
- 10 - Cofferdam
- 11 - Pump pit
- 12 - Movable high-pressure pumping station
- 13 - Rail track for pumping station
- 14 - High-pressure pump water supply main No. 1
- 15 - High-pressure pump water supply main No. 2
- 16 - Roller
- 17 - Working water pipe-lines for high-pressure pump 48 m long
- 18 - Working water pipe-lines for high-pressure pump 24 m long
- 19 - Flexible rubber hose 100 mm dia.
- 20 - Hydromonitor

FIG. 1-16

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**EVALUATION OF ALTERNATIVE
WET PEAT MINING SYSTEMS**

**GENERAL ARRANGEMENT OF
NEW STANDARD MACHINERY
IN A WORKING PIT**

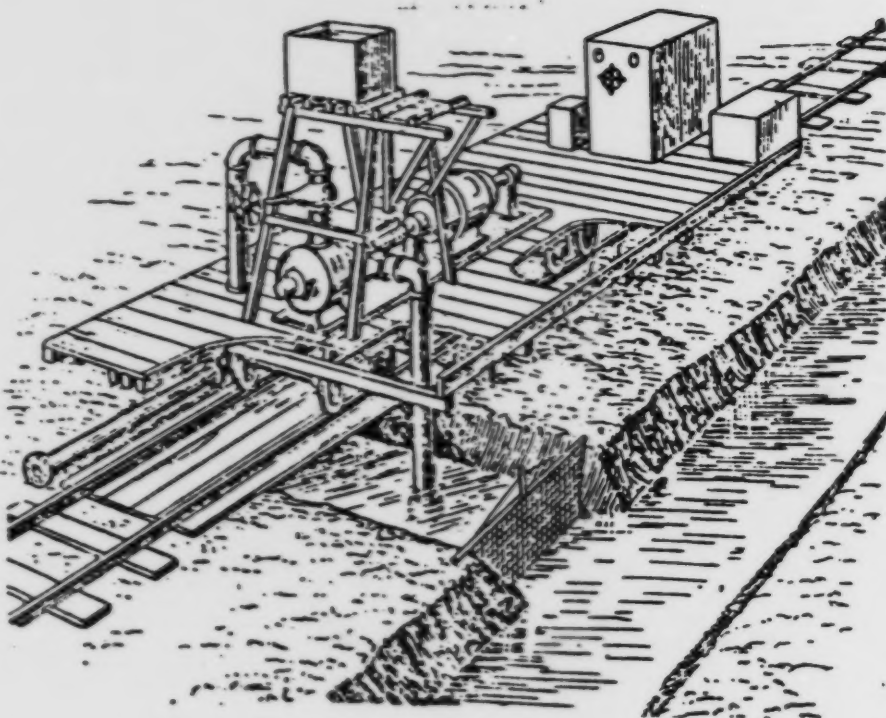


FIG. 1-17

NATIONAL RESEARCH COUNCIL

**EVALUATION OF ALTERNATIVE
WET PEAT MINING SYSTEMS**

**MOVABLE HIGH PRESSURE
PUMPING STATION**

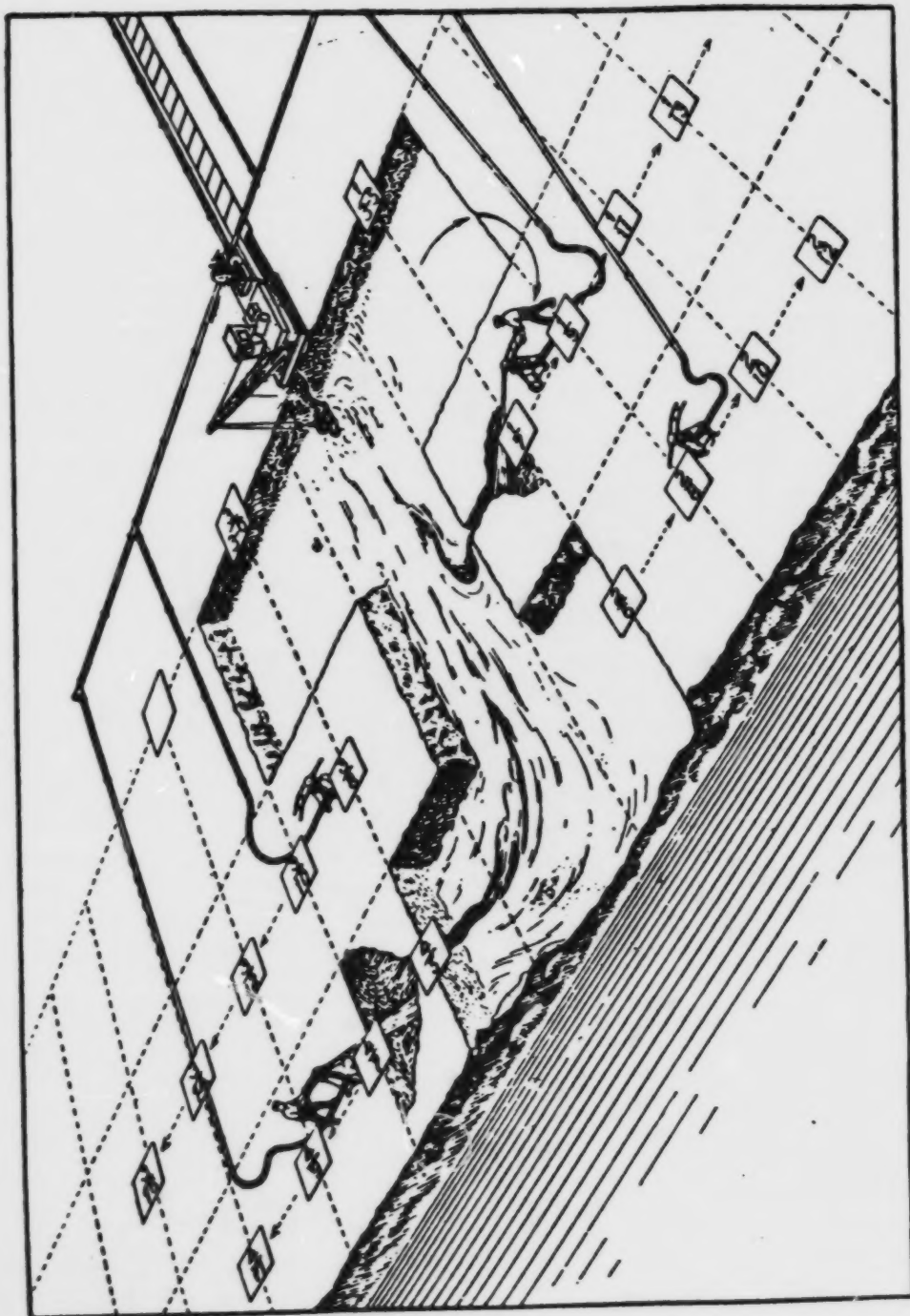
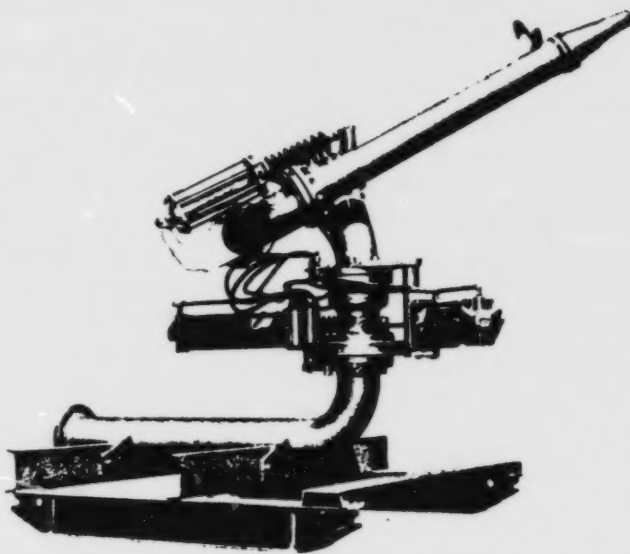


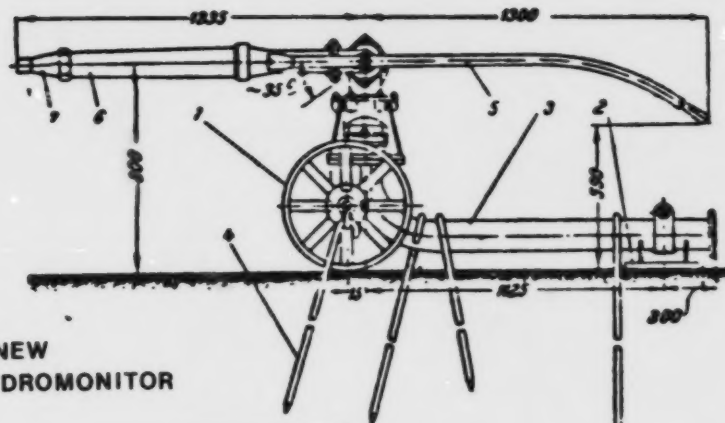
FIG. 1-18

NATIONAL RESEARCH COUNCIL
EVALUATION OF ALTERNATIVE
WET PEAT MINING SYSTEMS
VIEW OF WORKING PIT AREA
(NEW STANDARD EQUIPMENT)



STANG WATER CANNON

(mining guns for hydraulic mining or slurring,
typically used in Florida pebble phosphate fields)



**DETAILS OF NEW
STANDARD HYDROMONITOR**

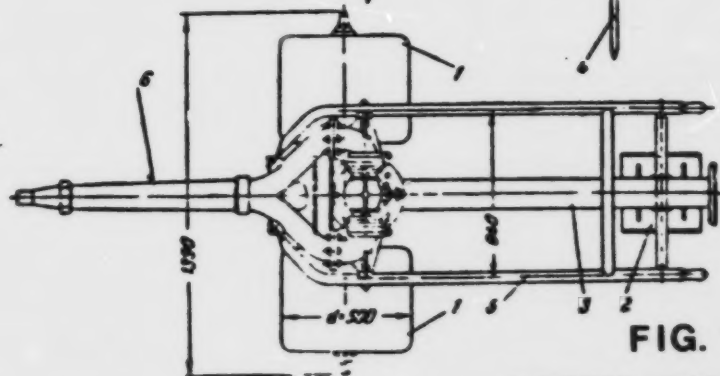
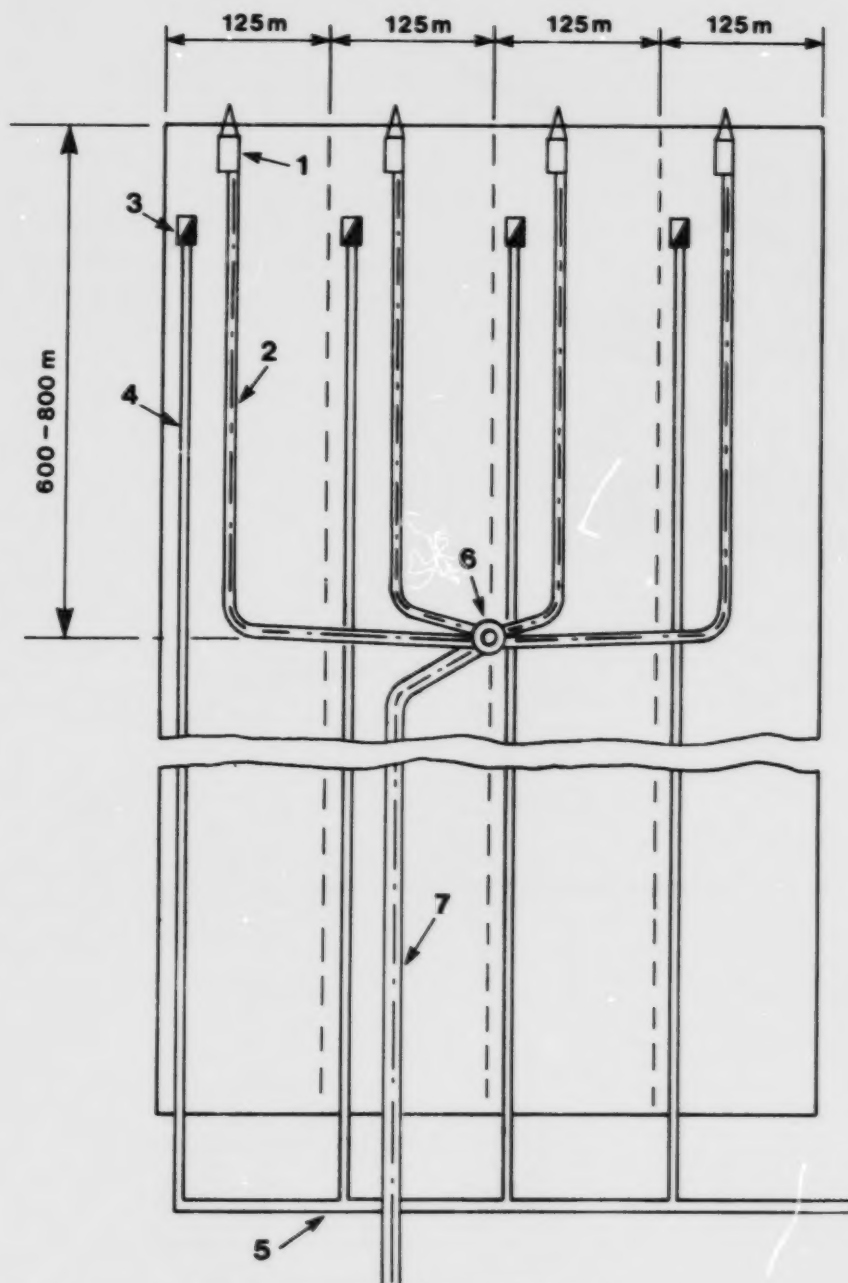


FIG. 1-19

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**EVALUATION OF ALTERNATIVE
WET PEAT MINING SYSTEMS**

DETAILS OF HYDROMONITORS



1. N.S. rail crane with mining peat slurry pump and equipment for clearing stumps in mining funnel
2. Crane slurry pipeline
3. Movable high-pressure pumping station
4. Open water tributary ditch
5. Water distribution channel
6. Intermediate peat slurry reservoir
7. Slurry pipeline

FIG. 1-20

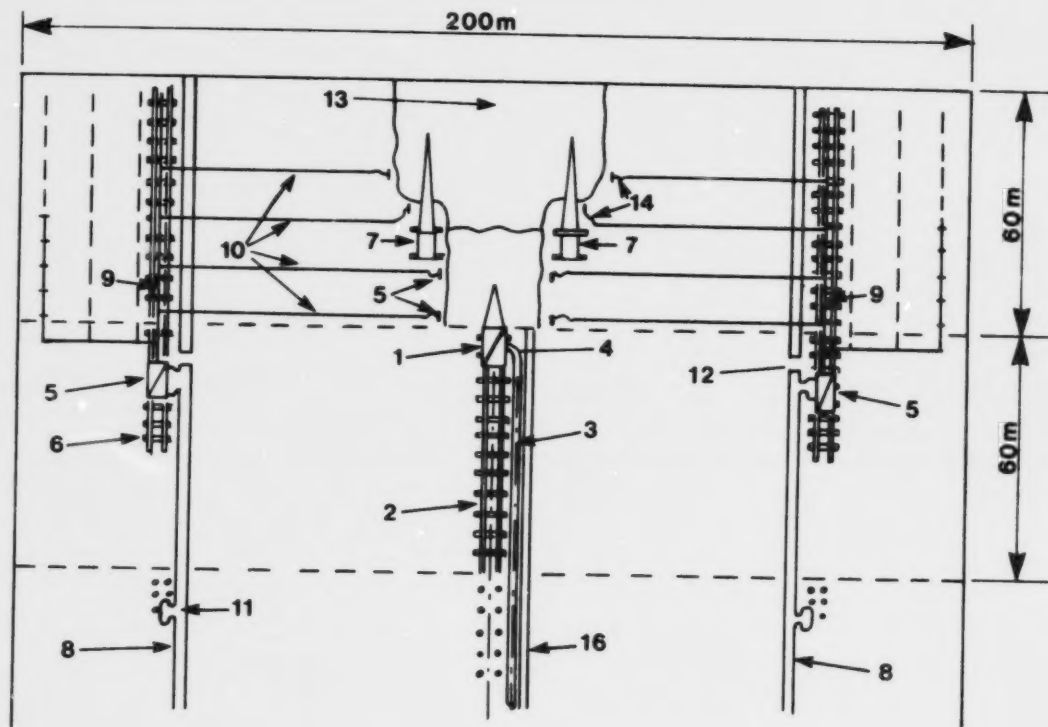
NATIONAL RESEARCH COUNCIL

EVALUATION OF ALTERNATIVE
WET PEAT MINING SYSTEMS

GROUPS OF EQUIPMENT SETS
PUMP SLURRY TO
COLLECTING RESERVOIRS



monenco



- 1- Rail crane S.S. with peat slurry-pump and equipment for clearing stumps in open peat slurry funnel
- 2- Rail track for crane
- 3- Crane slurry pipe-line 755 mm dia.
- 4- Telescopic joint
- 5- Movable high-pressure pumping station
- 6- Rail track for pumping station
- 7- Excavator with extra long swing boom
- 8- Open water tributary ditch
- 9- High-pressure pump water supply main
- 10- Working water pipe-lines for high-pressure pump
- 11- Pump pit
- 12- Cofferdam
- 13- Trench
- 14- Flexible rubber hose
- 15- Hydromonitor
- 16- Open drainage ditch

FIG. 1-21

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EVALUATION OF ALTERNATIVE
WET PEAT MINING SYSTEMS

GENERAL ARRANGEMENT OF
SUPER STANDARD MACHINERY
IN A WORKING PIT

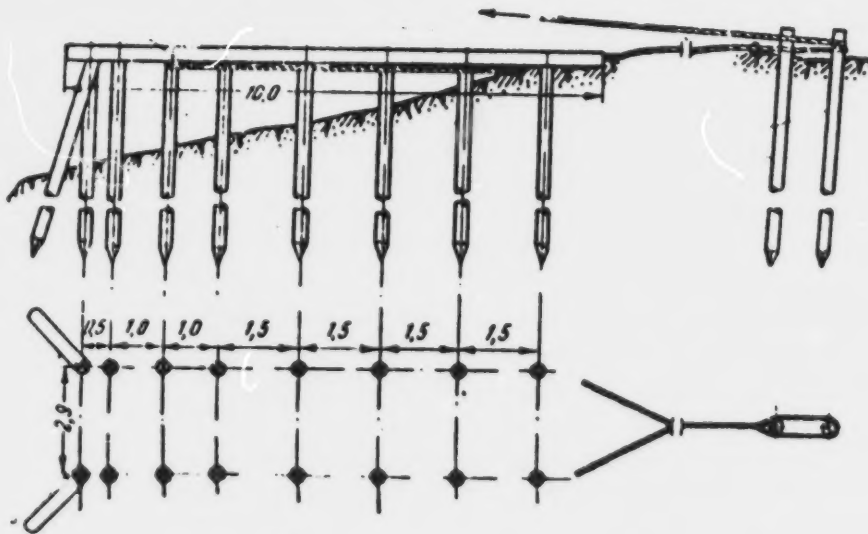
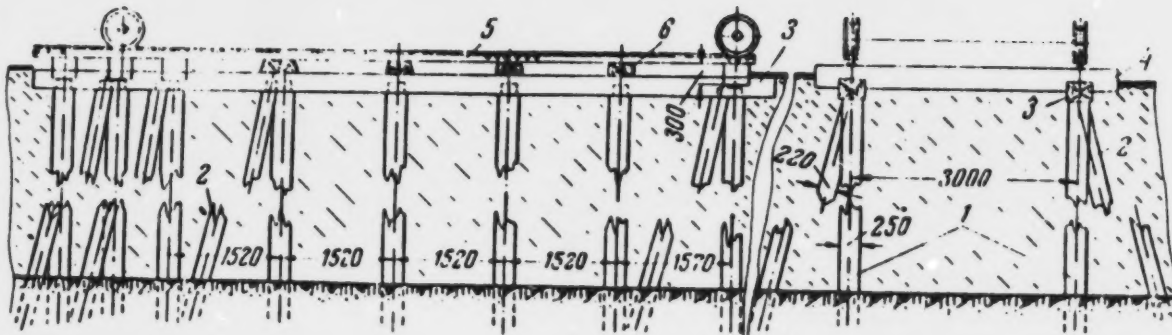


FIG. 1-22

NATIONAL RESEARCH COUNCIL

**EVALUATION OF ALTERNATIVE
WET PEAT MINING SYSTEMS**

**PILINGS FOR SUPPORT OF
NEW STANDARD EQUIPMENT
(REQUIRED FOR CERTAIN
PEATLAND CONDITIONS)**

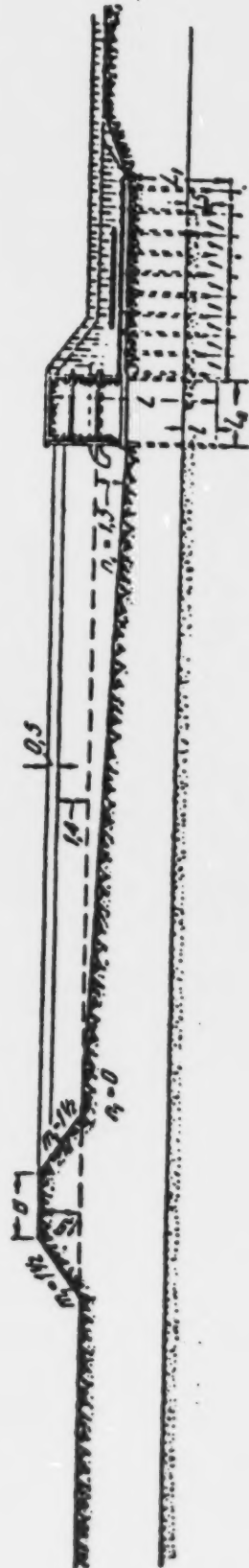


FIG. 1-23

NATIONAL RESEARCH COUNCIL

EVALUATION OF ALTERNATIVE
WET PEAT MINING SYSTEMS

1500 m³ CAPACITY PEAT SLURRY
TRANSIT RESERVOIR

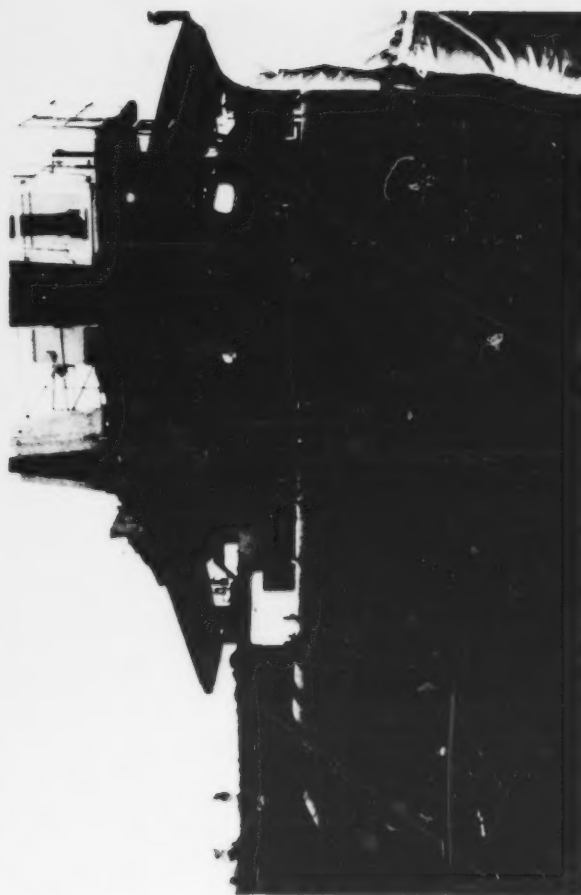
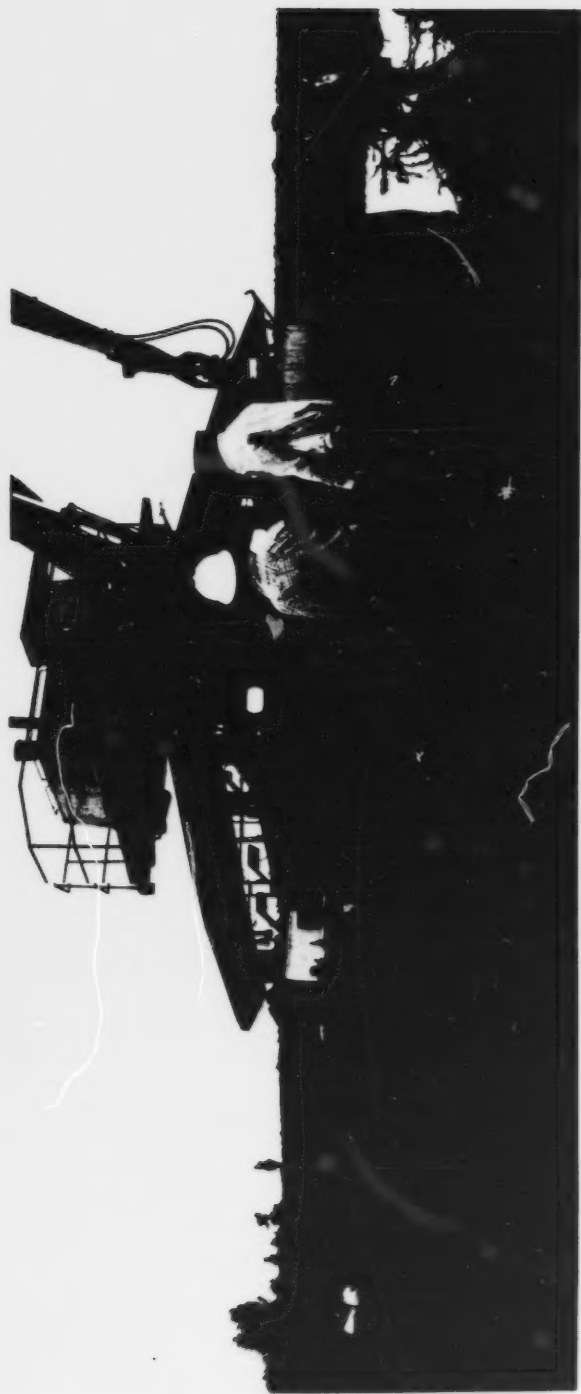


FIGURE 1-24 VANCOUVER HOVER BARGE

PART 2

TECHNICAL ASSESSMENT OF VARIOUS WET PEAT MINING
METHODS AND TECHNOLOGIES

PART 2 - TECHNICAL ASSESSMENT OF VARIOUS WET
PEAT MINING METHODS AND TECHNOLOGIES

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2.0 TECHNICAL ASSESSMENT OF VARIOUS WET PEAT MINING METHODS AND TECHNOLOGIES

2.1 INTRODUCTION

In selecting wet peat mining methods for further detailed technical assessment, only methods were chosen which fulfill certain requirements: production of a standard quality of feedstock for use in a processing plant for fuel production; utilize equipment which is presently commercially available; effective peat recovery, etc. Figure 3-1 and Figure 4-1 illustrate the various wet peat mining schemes selected for consideration. The technical assessment considered the following significant factors:

- a) mining technology requirements, e.g.
 - sufficient mineable peat resources,
 - moisture content of raw peat, and
 - depth of the peat deposit.
- b) quality of the feedstock suitable for further processing for fuel production, e.g.
 - degree of decomposition,
 - ash content,
 - peat slurry solids content,
 - peat slurry viscosity,
 - slurry preparation.
- c) technical considerations related to the separation of stumps, roots and other debris,
- d) utilization of mineable peat deposit,
- e) peat production equipment and manpower requirements,
- f) mining and transport system design methods,
- g) mining season, climate and weather,
- h) preparing the peatland for production,
- i) water and energy requirements,

- j) determination of equipment size,
- k) suitability of transport systems on drained and undrained bogs,
- l) cost factors affecting selection of mining method, and
- m) value of the reclaimed peatland.

The following sections explain why each of these factors play an important role in the selection of the wet peat mining methods best suited for Canadian conditions.

2.2 MINING TECHNOLOGY REQUIREMENTS

221 DEPOSIT SIZE, THICKNESS AND MOISTURE CONTENT

A mineable peat deposit must be large enough for the intended scale of operation. The boundary of the mineable area is usually set at a certain minimum peat thickness and is determined from the previous peatland survey information. However, to determine the amount of mineable peat for the selected mining method, only the portion of the deposit that maintains, typically, an average minimum depth of 1.5 m is taken into account. The depth of the deposit is also an important factor in the selection of specific mining equipment. The moisture content of the in-situ peat is another important factor for mining and transport as well as for processing. The practical yield of peat from one cubic meter of raw peat (i.e. average yield of air dried peat with 50% moisture content) can be calculated from the following formula:

$$p = \frac{W \cdot dr \cdot B}{dy} \text{ (tonnes)}$$

where:

p = yield in tonnes of air-dried (50% moisture content) peat from 1 cubic meter of raw peat.

W = volume weight (tonnes) of 1 cubic meter of raw peat at given degree of decomposition.

dr = solids content of deposit (% by weight).

dy = solids content of mined peat product (% by weight) taken to be 50%.

B = peat loss coefficient.

An optimal wet mining operation on a drained bog requires that the moisture content be 89.5-91.5% for a highmoor bog and 86-88.5% for a lowmoor bog. As the above formula indicates, the higher the solids content in the raw peat the higher the practical yield of peat from 1 cubic meter of raw peat.

2.3 QUALITY OF FEEDSTOCK FOR FUEL PEAT

Through extensive research carried out over a long period on peat and its use as a fuel, especially its physical and physicochemical properties, it has been determined that the quality of peat is of primary importance in the design and selection of mining technology.

231 DEGREE OF DECOMPOSITION, PEAT TYPE

The various peat types found in nature are characterized by a number of properties, one being the degree of decomposition which often is the basic property determining the mode of utilization. Peat in its natural form contains varying quantities of living, recognizable plant matter and remnants of partly decomposed plants as well as the darker, more morphaus products of decomposed plant material collectively called humus. The latter may or may not be soluble in water and is a brew of a large number of organic compounds of which the humic acids are probably the best known, if not by their chemical structure, by their name. During the process of the decomposition the peat becomes richer in humus which affects its physical properties.

The degree of decomposition reflects the carbon content of the peat, and subsequently to a large degree its calorific value. It is known that fuel peat has a high volatile matter content, containing between 68.5-75.5% and averaging about 73% volatile matter in the combustible mass.

The calorific value of the combustible mass of fuel peat depends on the chemical composition of the bog plants and the degree of decomposition. For example, the calorific value of highmoor peat at 30% decomposition is 5,500 kcal/kg (ash free basis), and lowmoor peat at more than 35% decomposition on average is about 5,750 kcal/kg (ash free basis). Fuel peat should have a degree of decomposition not less than 15%. Degree of decomposition is an important indicator of the fuel value of peat.

Considerable information used in this report was made available from previous experience in the U.S.S.R. on wet mining technology. Since degree of decomposition in this work is expressed as percentages versus the von Post system scale 1-10 commonly used in Europe and Canada, it was considered useful to include in this report a comparison of the two methods of determining the degree of decomposition. It should be noted that the von Post method has been proven to be very practical for field work. It is somewhat subjective

and is dependent on the experience and training of the surveyor. The Pjamtshenko method is a laboratory technique based on the interdependence of the degree of decomposition (humification) and the volume weight of peat. Pjamtshenko's percentage of decomposition expresses the percentage of humus (which is a result of decomposition of the organic matter) of the total organic matter (peat). Previous work has been carried out by Sarasto(1960) comparing the two methods and developing a correlation between them. They appear to correlate well and Figure 2-1 shows the distribution of Pjamtshenko's decomposition percentages in relation to the von Post degrees of humification. The reader is referred to the paper by Sarasto for more details.

In this report, the following terms have been used to describe peatland conditions:

- Highmoor: is derived from the German 'Hochmoor' and is related to raised bog conditions. As far as peat is concerned, highmoor is composed mostly of peat where sphagnum predominates, degree of humification is low, ash content is low, moisture content is high, bulk density is low, BTU value is low and the peat is mostly best suited for horticultural purposes. It is often referred to as moss peat in North America (oligotrophic, ombrotrophic, ombrogenic).
- Lowmoor: is derived from the German 'Niedermoor' and is related to fen-type conditions. Reed-sedge dominated peats, medium to high ash content, medium moisture content, pH is about 4.5-5.5, high BTU values, high bulk density, high degree of humification is typical. Suitable for fuel purposes and for in-situ agriculture and forestry. In North America it is often referred to as reed-sedge peat (eutrophic, minerotrophic, minerogenic).
- Transitional: is derived from the German 'Übergangsmoor', in between conditions; a transitional form between highmoor and lowmoor.

In nature, nothing is simple and pure. Depending on conditions, one can find even within the same deposit a continuum from lowmoor through transitional to highmoor conditions, and thus a wide variation in the peat quality.

232 ASH CONTENT

After combustion of the peat, ash is formed. Ash is the mineral matter of the peat and includes remnants of bog plants (primary ash) and mineral compounds brought into the peat deposit from the outside (drift ash).

Saturation water in highmoor bogs comes from atmospheric water and therefore the ash content of highmoor peat contains almost only plant ash. Saturation water in lowmoor bogs comes from atmospheric, surface and also from ground water. Therefore, these types of peat bogs usually contain more ash than highmoor peat. Highmoor peat ash content is on average 3-4% and lowmoor peat is usually up to 10-16%.

Drift ash is an undesirable impurity which lowers the calorific value of the end product, lowers the fluidity of the peat slurry during transportation and clogs the pipeline. Experience has shown that, depending on depth of the deposit and the stability of the underlying mineral soil, the amount of drift ash in the peat slurry ranges from 3-5%. Other sources of drift ash may be mineral matter carried by flood waters onto lowlying deposits and aeolian sand in arid areas.

Generally, peat mined by the milling method has the same ash content as the in-situ raw peat, whereas peat mined by hydraulic methods generally has higher ash content than the raw peat due to contamination by drift minerals. The melting point of the ash is an important factor for utilization of peat as a fuel. Generally, low-fusion point ash causes difficulties during the combustion process. Highmoor peat ash is characterized by medium fusibility and lowmoor peat ash is characterized by low fusibility. The quality of peat and its suitability for utilization as a fuel is ruled by various standards; for example, the ash content should not be higher than 23%.

233 PEAT SLURRY SOLIDS CONTENT

The peat slurry is a hydromass (suspension) containing, on average 93-97.25% of water and 7-2.75% of dry matter (by weight). The technology of wet peat mining is such that there are contrasting requirements on the solids content of the peat slurry, e.g:

- On the one hand it is important that the peat slurry have a high fluidity, in order to flow easily (when hydromonitors are used) to the slurry pump, which transports the slurry via pipeline for a considerable distance; the fluidity of the peat slurry increases, other conditions being equal, with increasing content.
- On the other hand, it is important to maintain the peat slurry solids content as high as technically possible in order to achieve a high production of final peat product. For this reason, the mining operation must strive to achieve a maximum solids content in the peat slurry.

The peat slurry solids content depends on the following factors:

- Quantity of water required for transformation of the raw peat into a liquid hydromass and, other things being equal, it will decrease with an increasing degree of

decomposition (and consequently the solids content in the hydromass will increase).

- Experience has shown (and confirmed by laboratory tests) that to obtain optimal pumping characteristics and maximum practical yield, that peat with a degree of decomposition of about 25% gives a low solids content in the peat slurry - about 3.4%. When peat has a higher degree of decomposition, about 45-55%, the practical solids content in the peat slurry is about 5-6% and in some cases 7-8% (see also Section 4 for a more detailed discussion).
- The solids content in the hydromass decreases if a hydromonitor is used and large blocks of raw peat are cut from the bog. Slurrying such large pieces requires large amounts of water which consequently decreases the solids content in the slurry.
- Stumps and roots found within the peat deposit also cause a decrease in solids content in the hydromass, since a longer time is required to free the peat from binding roots when using either waterjets and screens or hydromonitors. The amount of water also increases when additional water is needed to enable the slurry to flow through the stumps and roots. As a rule, the best quality peat clings to the stumps and roots. For this reason it is necessary to clean up the bottom of the pit at regular intervals.
- When using hydropeat equipment freezing in the working pit so considerably decreases the solids content in the hydromass, since a longer time is required using the water jet to free the peat from the frozen ground.
- The size of the working pit (hydropeat mining) is also an important factor. It must be dimensioned so that the larger particles will not settle on the bottom of the pit. Generally, the greater the distance to the peat slurry pump, the greater the amount of water required to make the slurry flow, and consequently the solids content in the hydromass decreases rapidly with an increasing amount of peat slurry in the working pit.
- The level of peat slurry in the working pit (hydropeat mining) has to be controlled to provide a minimum solids content of 2.75%. If the level of the peat slurry in the pit is too high, the solids content of the hydromass will decrease.

The method of determining the solids content in the peat slurry is important since not all methods produce accurate results. Determination of the solids content of the slurry produced by a wet

mining operation is the subject of detailed investigation. It starts with solids content analyses of the drill hole samples taken from the peatland survey. Each different peat type layer throughout each sample is subjected to botanical analysis and ash, degree of decomposition and slurry content (% solids) determinations. The results form a 'geobotanical spectrum'. Based on previous information which predicts slurry solids content based on knowledge of peat type and degree of decomposition, an average value of solids content can be calculated at each sample site.

The above method determines only the solids content of a peat slurry which can be obtained by a water jet under ideal conditions. To obtain the actual solids content of the peat slurry, certain correction coefficients must be used which take into account working pit size, stumps content, freezing occurrence, etc.

234 PEAT SLURRY VISCOSITY

One of the main physical properties of the peat slurry as of any liquid, is viscosity, that is, the internal properties of the fluid which offer resistance to flow. The unit of viscosity is the poise equal to grams per cm. sec. The viscosity of a peat slurry is a major indicator of its flow characteristics to the minimum peat slurry pump and for pumping via a pipeline. The higher the viscosity of the peat slurry, the lower its fluidity.

It has been determined that the coefficient of conventional viscosity depends on:

- peat slurry solids content;
- velocity of flow (hydromass stream);
- type of peat;
- degree of decomposition of the peat;
- temperature of peat slurry; and
- degree of maceration of the peat.

The coefficient of conventional viscosity of the slurry is an important factor for calculation of friction losses in the transporting pipeline. The quality of maceration of the peat slurry is very important for peat with a low degree of decomposition.

Information based on many years of experience with wet peat mining methods in the U.S.S.R., shows some very important peat slurry properties. For instance, at higher flow velocities the friction

losses in the peat slurry are lower than in water. Yevreinov explains this phenomenon: "Generally, turbulent flow conditions for liquid flow in a pipeline is distinguished by two zones, a boundary layer zone and a core flow zone. The boundary layer zone is characterized by the development of eddy currents (as a result of the contact of the stream with the pipe wall) progressing into the centre (core) of the flow. The eddy currents are further developed in the core of the flow, in low viscosity liquids, which brings the whole stream into a turbulent condition. Since a peat slurry has a higher viscosity it can be assumed that the eddy currents originating at the boundary layer (at the pipeline wall) do not develop further, therefore the whole stream does not develop into a turbulent condition. Consequently, under partial turbulence, the friction losses (for known velocities) will be lower than in water because the flow condition of water is turbulent (causing higher resistance)".

Knowledge of the magnitude of the peat slurry viscosity is indispensable for the calculation of friction losses, and it can be determined by a viscosimeter. Determinations of viscosity by a viscosimeter is performed at various speeds of the test cylinder in the peat slurry sample. For example, Figure 2-2 shows the viscosity characteristics of a peat slurry obtained for peat from a highmoor bog with a degree of decomposition of 40% (at various peat slurry solids contents). Using procedures to calculate friction losses, the results of the viscosity analysis are shown by a curve of absolute viscosity shown on Figure 2-3. Figure 2-3 shows a line of solids content of an industrial peat slurry. The cross point of the line with the viscosity curve determines the peat slurry solids content and the magnitude of the absolute viscosity.

235 SLURRY PREPARATION

The process of maceration of the raw peat is very important and deserves special attention for two reasons: to maintain a smooth mining operation and to produce a high quality end product. The importance of maceration to reduce the viscosity of the peat slurry has been explained in the previous section on viscosity. A lower viscosity of peat slurry results in lower friction losses and consequently requires less energy to overcome resistance in the pipeline. When mining peat using hydromonitors, the pressure of the water jets play an important role in the maceration process.

When using the hydropeat method, maceration of the peat occurs partially in the mining peat slurry pumps and partially during transportation of the peat slurry in the pipeline. Laboratory and field experience on peat slurry preparation has shown that a peat slurry possesses different degrees of maceration at different stages in the mining and pumping process (see Table 2-1).

Table 2-1: Levels of Maceration of Peat Slurry

Stages of the Wet Peat Mining and Transport Operation	Degree of Maceration (%)
High Pressure Water Jet	50.0
Peat Slurry Suction Pump	44.0
Peat Slurry Pipeline	6.0
Total:	100.0

The importance of the maceration depends, to a great degree, on the type of peat and degree of decomposition. Maceration is particularly important for a type of peat with a degree of decomposition of less than 30% since the many fibers require cutting, grinding and mixing. Lowmoor peat greater than 30% degree of decomposition also requires "processing", i.e. grinding, mixing, squashing to improve peat slurry flow characteristics.

2.4 TECHNICAL CONSIDERATIONS RELATED TO THE SEPARATION OF STUMPS AND ROOTS

Methods of separating stumps, roots and other large undesirable objects from the peat bog during mining, affect, to a considerable degree, the selection of mining equipment and methods. For instance, when using a hydraulic cutterhead dredge for mining peat (which can cut the stumps and roots found in the peat bog) the peat slurry is saturated with a large quantity of wood particles which can negatively affect the capacity of the peat slurry pump (i.e. frequent clogging) and the quality of the peat slurry feedstock to the process plant. Another example can be demonstrated by the mining of peat by a backhoe or clamshell excavator. These mining methods require a technical solution to separate the peat from stumps, roots and other impurities which has been found, for instance, at the Fisons-Western Inc. peat operation near Vancouver, B.C., by using a "Rader" system for removing stumps and roots (see Figure 2-4).

The "Rader" system separates stumps and roots from bulk raw peat with relative ease. However, experience shows that small roots and woody parts, smaller than 1/4", are not screened out and fall into the hydromass, and can clog the slurry pump. Another type of stump and root separator used with "Bagger" equipment is shown in Figure 2-5.

The main elements of the separator in Figure 2-5 is a table with six rocking keys mounted parallel with each other. The keys are equipped

with special teeth which assist in stump motion to the discharge point and rejection of the surface layer sphagnum lumps. The keys are mounted on two parallel crank shafts, one of which is driven by a motor through a drive shaft. The peat falls through clearances between the keys into a receiving trough on the apron conveyor, and the stumps are rejected by the keys onto the bog surface.

When mining peat using hydromonitors, the stumps and roots float in the hydromass and together with the peat slurry move toward the slurry pump. It is important to periodically clear the pump funnel area of small stumps, roots and surface sphagnum lumps. During the clearing of the funnel area, the slurry pump is hoisted up by a lifting mechanism. The stumps are cleaned from the bottom of the pit by a special excavator equipped with a rake or a specially designed clamshell. The collected stumps are piled up along the wall of the working pit to strengthen the dam separating neighbouring working pits. Before setting up a wet mining method, it is first necessary to resolve the problem of separation and clearing of the stumps.

2.5 UTILIZATION OF MINEABLE PEAT DEPOSIT

Losses occur during mining operations and are divided into groups. The first group of losses comprises portions of peatland which cannot be used for the entire duration of exploitation, and include:

- rail lines, bog haulage roads,
- dikes left for overhead electrical lines, pipelines,
- areas for various industrial buildings.

Determination of these losses is based on experience.

The second group of losses includes:

- the lower layer of the peat deposit left for reclamation purposes,
- peat which cannot be excavated from under the stumps and a volumetric loss within the deposit due to the stumps rejection,
- frozen lands,
- coffer-dams dividing seasonal pits,
- unpumped peat slurry left in the pit bottom,
- losses due to certain technical restrictions, e.g., deposit too deep.

All the losses must be calculated to determine how far the mining equipment will travel during one mining season. In addition, further utilization of the excavated peatlands for agriculture or other use depends, to a great extent, on the calculation.

2.6 PEAT PRODUCTION EQUIPMENT AND MANPOWER REQUIREMENTS

Various mining and transport equipment for wet peat mining operations made in Canada, USA and various European countries have been reviewed. For example, during this study, Monenco engineers visited Holland to familiarize themselves with the performance of the Konijn Amphidredge equipment in difficult terrain. In addition a visit was made to the Fisons-Western Inc. peat operations near Vancouver, B.C. to study the wet mining equipment at this location. Valuable practical information about peat mining and transport technology (e.g. its capability, manpower requirements, etc.) was gathered which has served as a base for selection of recommended peat mining equipment.

The extensive experience with mining peat slurry pumps in the U.S.S.R., and the knowledge available of the methodology of calculating capacity of such pumping systems also assisted in the selection of appropriate peat mining and transport methods. To select the best suited mining equipment we have also considered manpower requirements for the mining and transport process. For example, after studying the wet mining methods used in the U.S.S.R., specifically the Hydropeat method, we have concluded that it is not advisable to recommend this method for Canadian conditions because the manpower requirement is too high. In the selection of suitable wet peat mining methods, special attention was paid to methods requiring low manpower.

2.7 MINING AND TRANSPORT SYSTEM DESIGN METHODS

Before a peat mining and transport system is designed it is necessary to have sufficient knowledge of the peatland (type of peat, moisture content of in-situ peat, degree of decomposition, ash content, stumps content, etc.) in order to select the most suitable method to obtain an appropriate quality of peat as a fuel. After a review and study of the available literature and technical papers on wet peat mining technology, we have concluded that, at the present time, no feasibility study exists which can explain how to apply a wet peat mining method, taking into consideration the specific characteristics of peat as a feedstock for fuel use. There exists in Canada and the U.S.A. a number of small scale wet mining operations, mining peat for horticultural use and using various mining methods and equipment which is commercially available.

The conceptual design methods used in this report (and recommended for subsequent detailed designs) are based on specific knowledge of peat as a substance having special properties and characteristics. For

example, in the calculation of the capacity of the peat slurry pump the peat slurry solids content has been determined. The diameter and length of pipeline calculation takes into account friction losses in the pipeline, velocity of flow, and viscosity of the peat slurry. In the calculation of friction losses, the viscosity characteristics and raw peat characteristics have been taken into account: the type of peat, its moisture content, degree of decomposition, etc., have been considered. In certain cases, specific information on Canadian peats has been lacking and assumptions have been made about similarities between Canadian and Russian peats for purposes of this work. Further detailed design would require detailed information and analysis of the site-specific characteristics of the peat to be mined.

2.8 MINING SEASON, CLIMATE AND WEATHER

The equipment utilization factor is an important consideration in the selection of the most suitable mining method. The number of working days in the season determines the amount of peat mined.

2.9 PREPARING THE PEATLAND FOR PRODUCTION

Preparation of the peatland for production usually includes the following activities:

- construction of the drainage network (channels, ditches, etc.),
- clearing of trees, shrubs and other forest remnants, and
- levelling of the surface.

A peat mining operation that does not require the above preparation work has a great advantage over a mining method which does require these usually expensive activities. At the same time, it is necessary to take into account that the costs of preparation of peatland on highmoor peat is usually higher than on lowmoor peat. For instance, industrial experience in Europe has shown that the costs for the preparation of 1 ha of highmoor peatland is 30-40% higher than for lowmoor peat. This occurs because the drainage system of a highmoor bog requires a more sophisticated network than on a lowmoor bog.

2.10 WATER AND ENERGY REQUIREMENTS

Some wet peat mining methods use high pressure water jets for slurring the in-situ peat in water. For example, water consumption for a set of equipment of the "New Standard" system (a Hydropeat

method variation used in the U.S.S.R.) was 300-400 cubic meters/h. To supply the mining operation with sufficient water it was necessary to build a special water supply system from the source uphill to the highest point on the peatland, where the water flowed by gravity in an open channel to appropriate tributary ditches and on to the mining equipment.

The capacity of the high pressure water pump delivering water from the source, is subject to:

- annual production (seasonal output) requirement,
- water delivery distance, and
- surface topography.

As well, the energy requirements for the mining and transport equipment were investigated for the various mining methods, including the possibility of replacing electrical motors with diesel engines. Thus, factors affecting energy supply requirements were taken into account when selecting the most appropriate mining method.

2.11 DETERMINATION OF EQUIPMENT SIZE

To secure an uninterrupted peat production supply to the process plant, it is necessary to fulfill the following conditions:

- quality of the peat slurry must be of a satisfactory standard for the required feedstock,
- the transportation system must supply a required amount of peat slurry without interruption, from the bog to the process plant,
- output capacity of the mining and transport equipment must be 15-20% higher than the output capacity of the process plant equipment, to allow for unpredictable operating losses.

In the selection of the most appropriate mining methods, factors affecting only the overlap of mining and process plant equipment were taken into account. Storage of the peat slurry (feedstock) was outside the scope of the report and has not been considered since detailed information was not available on the process plant technology, the process plant equipment and its capacity, and the type and method of storage.

2.12 COMPARISON OF TRANSPORT SYSTEMS ON DRAINED AND UNDRAINED BOGS

Selection of the best transport system from the bog to the process plant takes into account the following factors:

- suitability of the transport system for drained or undrained bogs,
- specific properties of peat as a transport material,
- use of conventional and commercially available equipment for the transportation of peat, equipment with proven performance, and
- the required transport distance.

2.13 COST FACTORS AFFECTING THE SELECTION OF MINING METHODS

The deciding factor for the selection of the best suited mining and transport method is the production cost, which includes capital and operating costs. Without this information, an economic assessment of various wet peat mining methods cannot be completed. Therefore, mining methods were evaluated that have a reasonable amount of cost information available for preliminary cost calculations.

2.14 VALUE OF RECLAIMED PEATLAND

In many European countries, close attention is paid to the restoration of the reclaimed peatlands for agriculture, forest and fish farming industry use which can bring a valuable contribution to the local economy. Generally, on highmoor peatlands which have layers of sphagnum peat on the surface, the bottom layer is often good quality lowmoor-type peat, which can be used for fuel and a small thickness can be left after mining to establish agriculture. The value of the crop yield from reclaimed highmoor or lowmoor peatlands is often the same.

Extensive European experience with the utilization of excavated peatlands for agricultural use shows that the most suitable and most recommended plants are common grasses which do not excessively disturb the organic horizon, as opposed to crop cultivation. For example, agricultural farms in the central U.S.S.R. have produced the following yields from 1 ha of reclaimed peatland:

- vegetables, 60-90 tonnes,
- hay, 9-12 tonnes,
- potatoes, 20-27 tonnes.

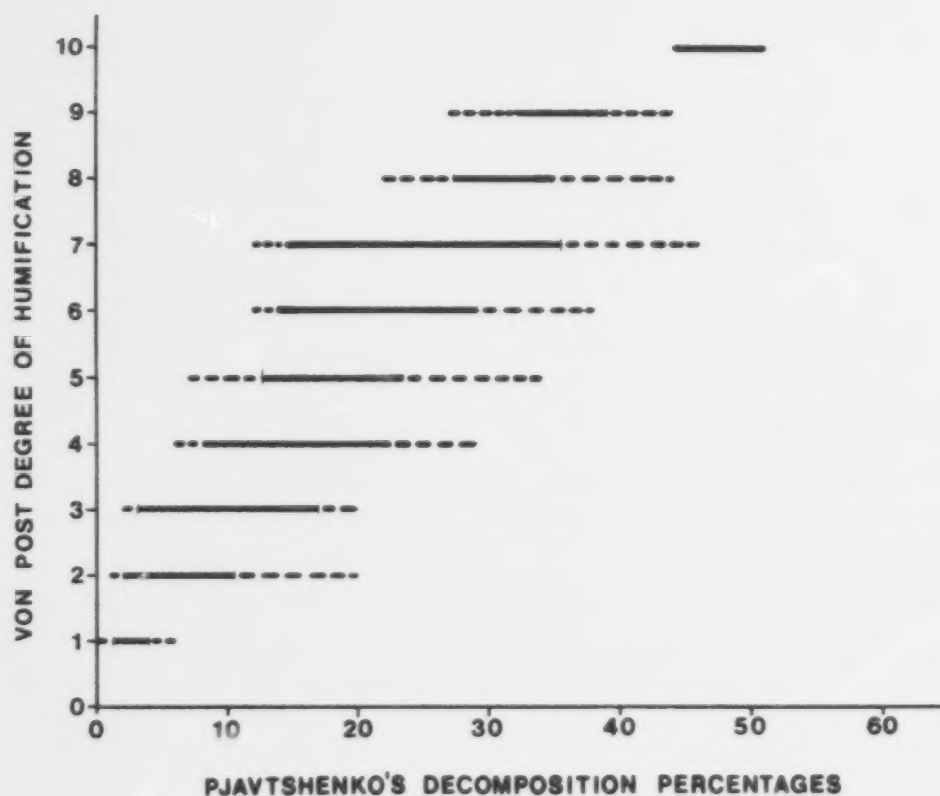
The excavated land can also be utilized as national parks (reserves) and certain peatlands, especially those mined by wet mining methods, are best reclaimed for wildlife purposes and for the cultivation of plants for use as feed for wildlife fowl and domestic fowl. Great interest has also been shown in utilization of reclaimed peatlands for a fish industry with promising results. Thus, an economic evaluation of the reclaimed peatlands is important for the planning of wet peat mining operations.

2.15 ENVIRONMENTAL CONSIDERATIONS

It is considered unwise to progress too far in the technical assessments and implementation of the peat mining and utilization technologies without parallel investigations into the various environmental factors associated with the potential peatland developments. Ideally, a complete inventory is required for the various peatland regions to categorize peatlands into suggested uses (or non-uses). Such a division of peatlands could include the following broad, general categories:

- a) peatlands suited for development by mining for use as a fuel, agriculture, coke, etc.
- b) peatlands which should not be drained because the impact will be too great on the hydrologic regime. These peatlands could possibly be used, or partly used, if drainage, or a severe change of the water regime was not planned, and
- c) peatlands which will not be used, but reserved for parks, wildlife habitats, certain types of protected tree or plant species, etc.

Certain projects could be undertaken to evaluate under Canadian conditions the effects of, for example, evaporation changes due to peatland drainage and other agriculture and forestry drainage programs. As well, the effect on surface temperatures caused by drainage, on the peatland and nearby areas, and changes in frost severity should be examined. Many other environmental factors are also involved in peatland development and have been considered in the preparation of this report.



SOURCE: SARASTO (1960)

FIG. 2-1
NATIONAL RESEARCH COUNCIL
EVALUATION OF ALTERNATIVE
WET PEAT MINING SYSTEMS
COMPARISON OF VON POST
DEGREE OF HUMIFICATION
WITH PJAVTSHENKO'S
DECOMPOSITION PERCENTAGES

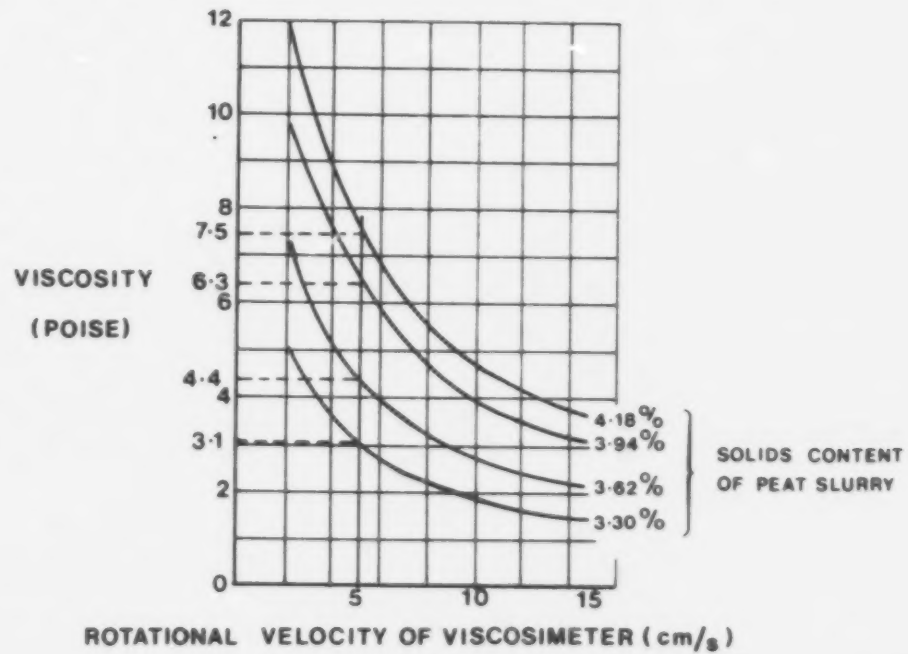


FIG. 2-2

NATIONAL RESEARCH COUNCIL

EVALUATION OF ALTERNATIVE
WET PEAT MINING SYSTEMS

**PEAT SLURRY VISCOSITY
CHARACTERISTICS FOR
HIGHMOOR PEAT
(DEGREE OF DECOMPOSITION 40%)**

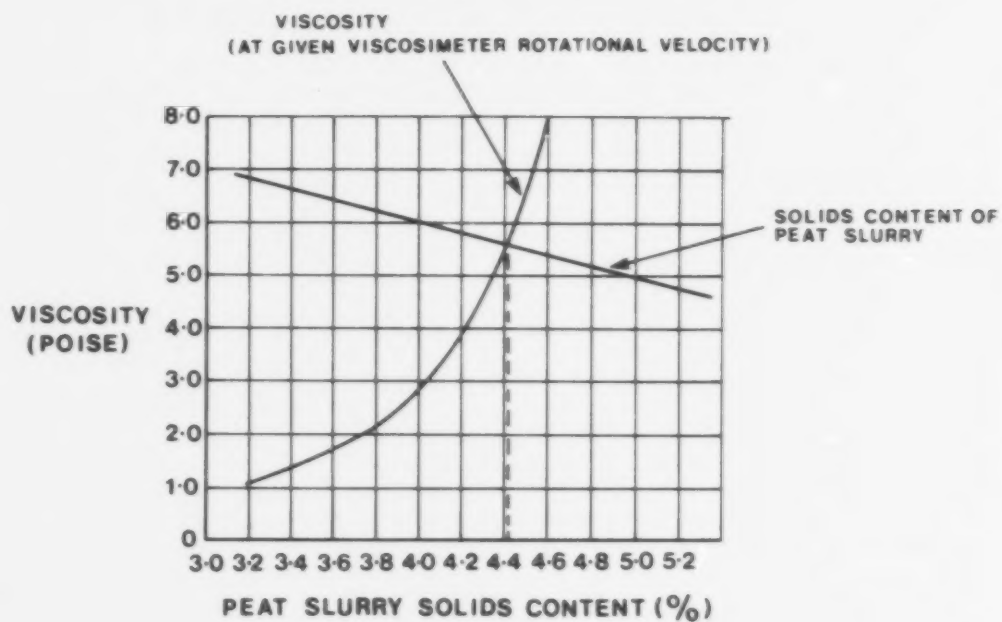


FIG. 2-3

NATIONAL RESEARCH COUNCIL

EVALUATION OF ALTERNATIVE
WET PEAT MINING SYSTEMS
METHOD OF DETERMINING
THE SOLIDS CONTENT
OF THE PEAT SLURRY

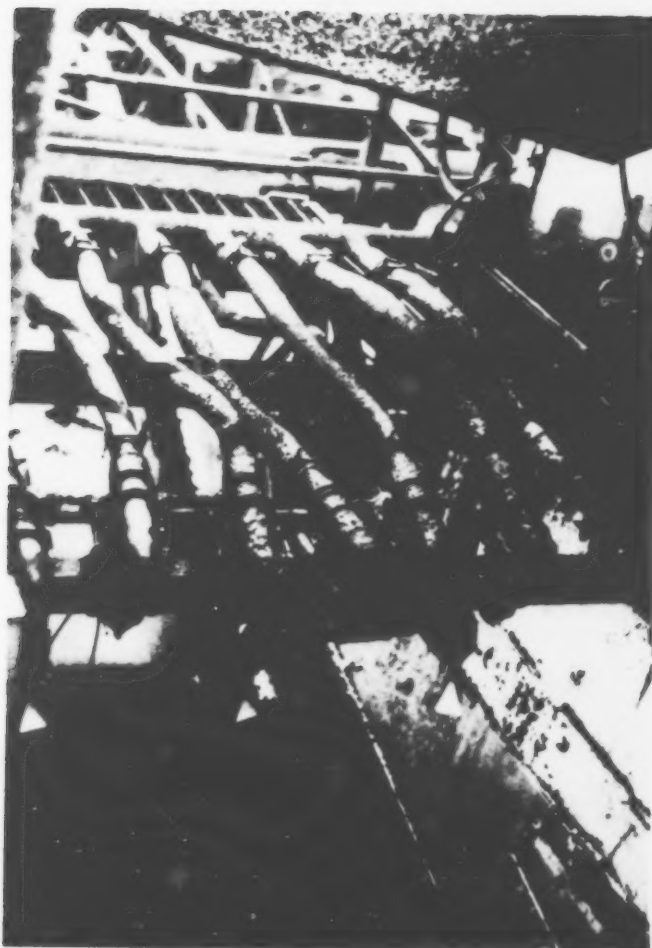
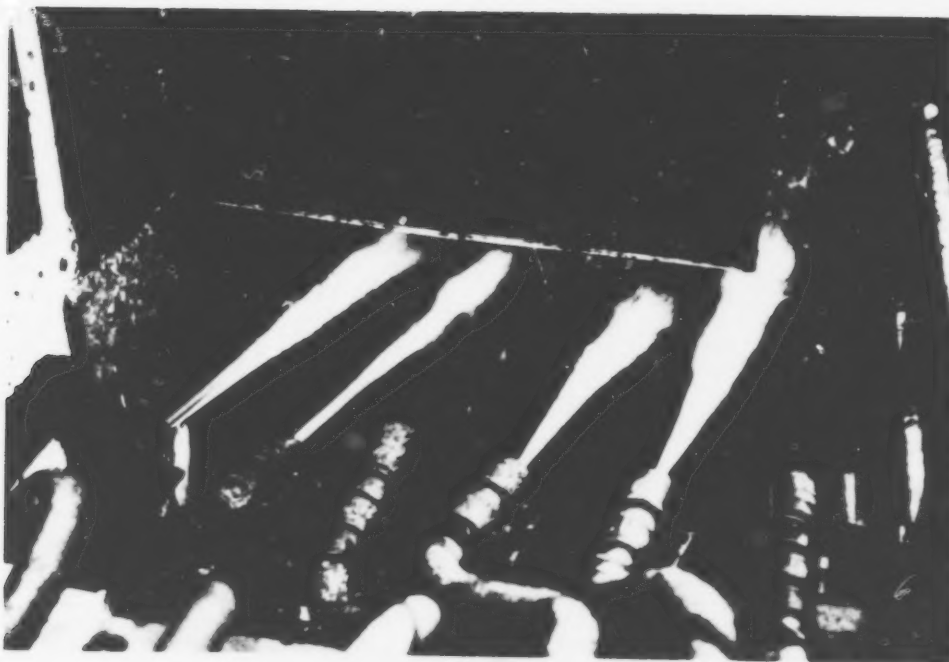


Figure 2-4
Rader Disc Screen System
(for separation of stumps & roots)

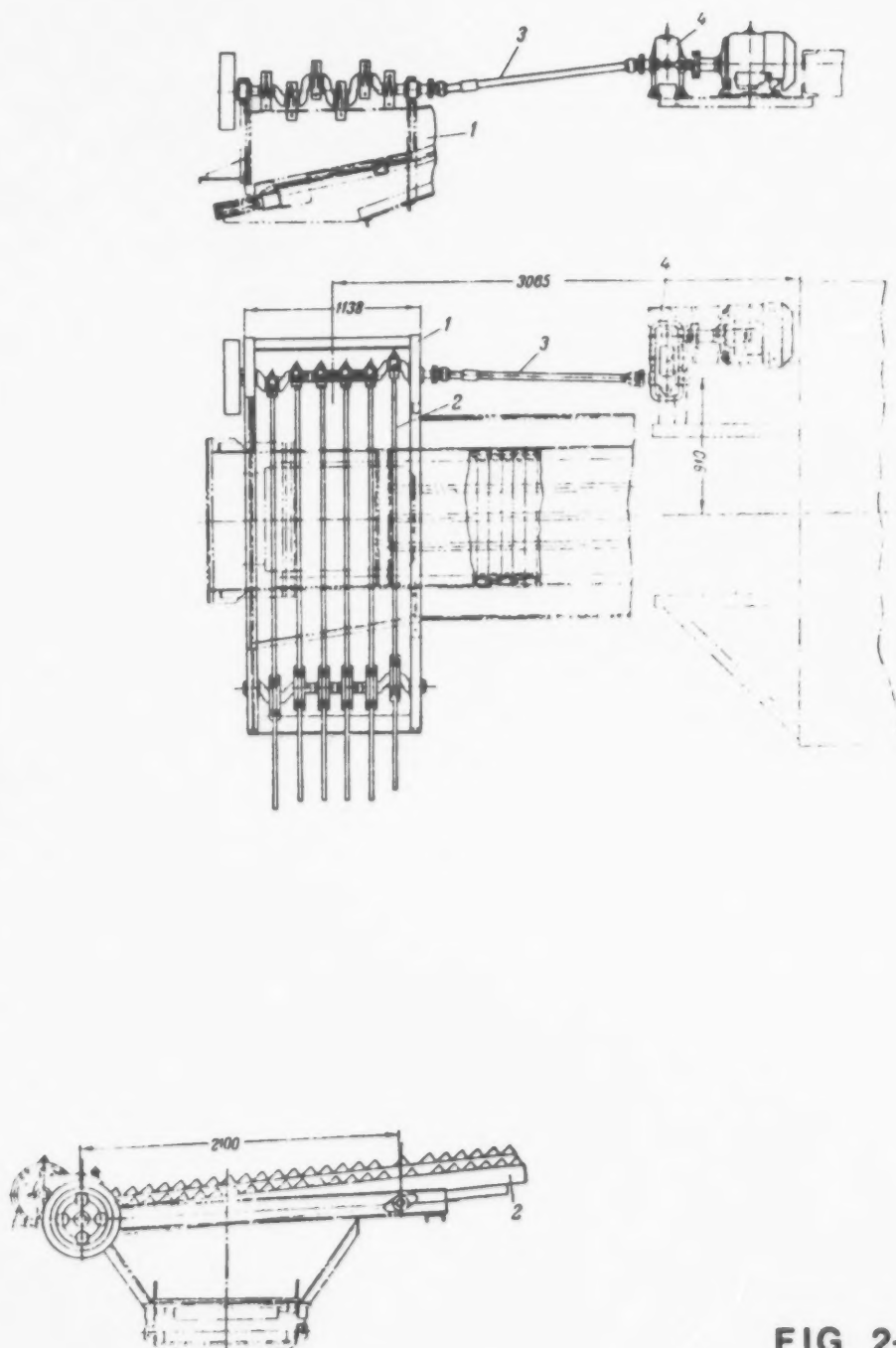


FIG. 2-5

NATIONAL RESEARCH COUNCIL

EVALUATION OF ALTERNATIVE
WET PEAT MINING SYSTEMS

**STUMPS AND ROOTS SEPARATOR
(USED WITH BAGGER SYSTEM)**

PART 3

MINING OF UNDRAINED PEATLANDS

PART 3 - MINING OF UNDRAINED PEATLANDS

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3.0 MINING OF UNDRAINED PEATLANDS

3.1 INTRODUCTION

This Part contains information on wet mining methods proposed for undrained (virgin) peatlands for small and medium sized applications (see Figure 3-1). Although this study has specifically excluded large scale cutter suction dredging technology, a brief discussion has been included on a small-scale, amphibious dredging system (Amphidredge) which can be used for mining peat.

To develop an actual wet peat mining system with a high probability of successful application in practice, or to successfully develop a peat processing technology, one must take into account the physicochemical characteristics of peat. For both the drained and undrained bog conditions, one has to consider the amount of harvestable peat within the deposit, the peat type, degree of decomposition, moisture content of the in situ peat, stumps content, ash content, peat depths, etc. For this study, peat data from deposits in Ontario, Quebec and Saskatchewan has been included (see Table 3-1).

Table 3-1 Characteristics of Some Typical Canadian Peat Deposits

Characteristic	Range	Average
Thickness of the sphagnum surface layer, (m)	0.2-0.3	0.25
In-situ peat depth, (m)	2.20-2.30	2.25
Moisture Content (%wet weight)	88.0-93.0	91.5
Stumps Content, %	up to 1.5	
Degree of Decomposition %	16.0-32.0	27.0
Ash Content, (% dry matter)	4.0-8.0	6.0
Calorific Values (kcal/kg)	4500-5500	5000

3.2 SMALL SCALE OPERATIONS

For purposes of this report, small scale peat operations are considered to be up to 50,000 tonnes per year of air-dried peat (50% moisture content). To calculate the yearly mining tonnage a number of factors have to be known, such as:

- harvestable area within the bog,
- mineable peat quantity,
- amount of peat to be left on the bottom (left for reclamation and some mining loss),
- other losses for embankments and due to frost, etc.

Calculations show that to achieve a 50,000 tonne per year production rate for a reasonable mine life, the deposit must contain about 37 million cubic meters of mineable peat or about 2000 ha at an average depth of 2.25m. The practical yield of air-dried (50% m.c.) peat from one cubic meter was calculated based on 96% moisture content in the raw peat, 27% degree of decomposition and a volume weight of raw peat of 1.01 tonnes/cubic meter. Another factor considered was the mining recovery using the Amphidredge set of equipment as selected for the small-scale wet peat mining operation.

The Amphidredge is a proven piece of equipment manufactured by the Konijn Export Group in the Netherlands and has been applied on small dredging operations in many countries. The canals in Amsterdam are routinely cleaned using this equipment. The suggested application of the Amphidredge to peat mining should not be construed as a recommendation of a particular manufacturers equipment. However, it is understood that the Amphidredge is patented and other manufacturers offering comparable machines could not be found. The Amphidredge has the following qualifications which appeared to suit it to the proposed peat mining applications:

- They are designed for dredging in wet or marshy conditions where conventional earth-moving machinery cannot be used effectively or cannot be used at all.
- The machines can cope with a wide variety of site conditions, including difficult (inaccessible terrain, swamps, etc.).
- Many different types and sizes of machine are available.
- They can be easily transported by truck or trailer to cope with situations involving small jobs at widely scattered sites.

- The manufacturer claims they are built for reliable operation over many years and that the standardization of components makes maintenance simple and inexpensive.
- Amphidredges do not compete with conventional land-based machines.
- Amphidredges may be used in difficult terrain such as swamps (H-series machines), for construction/dredging/exploration work and also in swamps for construction of canals, etc. without first having to build costly dikes such as required to carry land-based excavating equipment.
- Weed removal can be of importance in wet mining. This can also be done by Amphidredges, either with roots and all or by cutting with a moving bucket attachment.

Two different methods of wet peat extraction and transport will be discussed using the Amphidredge for small scale wet peat mining operations, namely:

- bulk peat excavation by Amphidredge, and
- milling cutterhead suction dredging by Amphidredge.

321 BULK PEAT EXCAVATION BY AMPHIDREDGE

The technical process of peat mining by this method is as follows:

- a clamshell or backhoe type excavator mounted on a standard Amphidredge excavates peat from the wet bog and dumps it onto the Rader-type separator. The Rader-type separator and other equipment is mounted on a separate barge or a specially-constructed larger Amphidredge used for preparing the peat slurry. The second larger Amphidredge is stationary while the first, smaller one excavates peat.
- On the slurry barge, water jet sprays wash the fuel peat through the separator into a slurry tank. The peat slurry is then pumped by the peat slurry pump through a pipeline to the adjacent process plant, possibly using an intermediate state of pumping, (depending on distance).
- Stumps, roots, lumps of moss peat and other debris rejected from the separator are conveyed and discharged back into the peat deposit or, more preferably, into barges for transport.

The above-mentioned operation is conceptually based in part on the wet peat mining system at Fisons-Western Inc. near Vancouver, B.C. where the method is used in principle on previously drained peatland.

Figure 3-2 shows a schematic of the small scale bulk peat excavating system using the Amphidredge-type equipment in undrained peatland. Information from the manufacturer demonstrates the equipment to be amphibious insofar as the machine can move itself from the bank into the water and vice-versa.

The Amphidredge series H400-4 has 4 legs and can manoeuvre over hills and into rivers or along canal banks to reach the dredging or excavating site. The H-400-4 model (standard size) is also capable of loading itself onto a flat-bed truck for ease of transport. The Amphidredge consists of:

- a main pontoon (sometimes supported by side pontoons)
- 3 or 4 movable legs, hydraulically operated, permitting travel by the vehicle by crawling (like a turtle). The legs also serve to provide firm support while excavating.
- a hydraulically operated clamshell or backhoe (or front-shovel) bucket.

The main specifications of the H-400-4 model, which was selected as the excavating piece of equipment for the small scale system, is shown in Table 3-2.

A key item in the small scale equipment set is the peat slurry pump. It is located on board the adjacent slurry barge or special Amphidredge and is sized to pump about 200-250 cubic meters per hour of peat slurry. A peat slurry holding tank providing maximum surge capacity to the pump is also required. The "processing" of the peat within the peat slurry pump is a very important aspect in the performance of the pump and the flow of the slurry in the pipeline. A specially-designed pump is required which cuts, grinds and macerates the peat fibers and small roots after the Rader-type separator. The pump should also have a propeller which continually mixes the peat slurry and promotes smooth operation of the pump. A review of pump models available in North America and Europe indicates that a pump with the special features required to pump peat slurry is not currently available. The above described peat slurry pump provides not less than about 50% of the total preparation of the peat slurry feedstock, including all activities from mining to transport of the slurry by pipeline to the process plant. Calculations show that a peat slurry pump operating at a capacity of about 200-250 cubic meters/h at a total head of 10-15 m can pump the peat slurry a distance of about 1.5 km.

Water is used to separate roots and other debris from the fuel peat. This is accomplished by means of water jet sprays located over the Rader-type separator. Sufficient water is required to carry out the separation and to prepare the peat slurry to the desired solids concentration (about 2.75 to 3.0% by weight). It is expected that an adequate supply of clear water can be obtained from the mining area.

Table 3-2 Characteristics of Amphidredge H-400-4

Contents of standard bucket	: 400 litres (750 litres optional)
Max. reach	: 6.70 meters
Max. dredging depth (backhoe)	: 4.50 meters
Max. dredging depth (grab)	: 5.50 meters
Weight	: 16.8 tonnes approx.
Production	: 70-100 cubic meters/h (150 cubic m. optional)
Excavator - rigid hydraulic backhoe	: 330 degrees rotatable
- excavating	: 240 degrees
Pontoon	: rigid steel welded pontoon with easily removable side pontoons (optional)
Transportation width	: 2.50 m
Mean bottom pressure/land	: 72 gr/cm2
Legs	: 4 hydraulic operated legs with marsh-wheels make it possible to: - swim while floating; - step and walk in swamps, mud and marsh-land, walking speed appr. 0.3 km/hrs; - stand on the bottom in water up to 4.20m deep (lengthened legs); - climb in and out of the water under its own power; - ride for short distances, pulled by a truck, speed appr. 3-6 km/hr; - climb on a truck for long distance transport;
Marshwheels	: fully rotatable, rotation lock for stable positioning
Engine	: DEUTZ aircooled, 5 cylinder diesel engine type F5L912, output of 58KW at 2150 rpm
Hydraulic pumps	: one triple gearpump and one double gear-pump for excavator and leg movements
length of pontoon	: 7.85 m
length with stretched legs	: 14.23 m
max. depth with standard legs	: 2.50 m appr.
max. depth with lengthened legs	: 4.20 m appr.
width with side pontoons	: 4.35 m
draft with side pontoons	: 0.88 m
max. discharge height	: 6.20 m
diameter of marshland wheels	: 1.10 m
width of marshlands wheels	: 0.52 m

Figure 3-3 and 3-4 show a small scale wet peat mining operation progressing through a peat deposit during production years 5 and 15. The depth of the deposit is assumed to be 5.5 m, which, although it is unusual to find peat deposits in Canada with any significant areal extent greater than 5 m deep, it will serve to illustrate a limiting case for application of the small scale wet mining technology. When operating, the equipment is placed in a stationary position using the lengthened legs of the Amphidredge (up to 4.2 m) which steady the equipment and provide a firm footing, depending on bottom conditions. In deeper deposits, and when soft bottom conditions are encountered, a different anchoring system is used.

Earlier, the separation of stumps, roots, etc. from the fuel peat was discussed. If, for reasons such as dike construction, environmental considerations, etc., it is required to transport the reject material some distance from the slurry barge site, small split hopper barges can be used. The Amphidredge is often used in conjunction with 15 cubic meter split hopper barges and a small push-boat (74 h.p.). The push-boat is not only used to move the barge from the loading to the unloading stations but can also assist in moving equipment on the water, service the floating pipelines and to transport supplies to the excavating site.

It is estimated that one set of bulk peat excavating equipment can produce about 50,000 tonnes of air-dried peat (50% moisture content) per season based on the following assumptions:

- transition-type (mesotrophic) peat bog;
- peat slurry solids content 3% (calculated taking into consideration stumps content, ash content, frozen lumps content, etc.);
- peat slurry make up water coefficient = 1.4;
- practical yield from 1 cubic meter of peat slurry (calculated) 0.051 tonnes (air-dried basis, 50% moisture content);
- 96% moisture content raw peat and degree of decomposition 27%;
- stump content of the deposit, up to 1.5%;
- slurry preparation, transportation and storage losses, 11%;
- 24 hours per day operation, 260 days per year (water level and slurry control requires continuous operation);
- overall utilization factor 0.75 which takes into consideration equipment moves, maintenance, servicing, periodic cleaning of the separator and pump system.

Calculations show that for a large 2000 ha peat deposit with about 37 million recoverable cubic meters of raw peat, 2 complete sets of production machinery would be required. Annual production of air-dried (50% m.c.) peat would be about 100,000 tonnes and the mine life would be about 20 years.

Figures 3-3 and 3-4 show wet and dry peat storage areas. It was beyond the scope of this study to consider the storage of the peat slurry, the storage reservoirs or methods of transporting the material from storage to the process plant.

322 SMALL-SCALE MILLING CUTTERHEAD SUCTION DREDGE

A small milling cutterhead suction dredge was considered for small-scale applications of wet peat mining on undrained peatlands after a review of the various equipment and methods available, including dredging. The Amphidredge equipment can be fitted with a cutterhead suction system which in many cases can be more economical than mechanical dredging. Amphidredge models S170 and S200 are manufactured for this purpose, supplied with or without legs. The equipment is designed specifically for maintenance dredging of silt and vegetational sediment. A pump is used for transporting the spoil through a discharge pipeline to the dumping site, which may be situated nearby or at a considerable distance.

Figure 3-5 illustrates the small scale milling cutterhead suction dredge. As described by the manufacturer, the S series type equipment has a cutter suction system consisting of:

- a (milling cutter) scoop for tunnelling silt or other loose deposits into the suction inlet, thereby enhancing the solids/water ratio. The milling cutter is suitable for dealing with vegetation, small branches, lumps of hard soil, etc. These components are combined in a way which improves the performance of the pump;
- a special pump with an impeller able to handle relatively large pieces of debris such as food cans, shoes, bricks, etc., thereby minimizing downtime due to clogging of the pump.

The dredging is done by winching the craft forward along a guide wire. On the S-200 model, additional steering is provided by a disc wheel on the rear leg(s). The dredges can be fitted with 3 or 4 legs, with the aid of which they can walk under their own power from the unloading station to the water and, when on site, around obstacles such as bridges. Table 3-3 summarizes the principal characteristics of the dredging equipment:

Table 3-3 Principal Characteristics of Amphidredge
S-Series Dredging Equipment

Machine	S170	S200
Max. dredging depth - forward	3.20 m	3.5 m
- backward	5.0 m	5.35 m
Production	50-80 cubic m/h	100-140 cubic m/h
Diameter of Suction Pipe	170 mm	200 mm
Engine h.p.	110 h.p.	165 h.p.

The system has the following features:

- the equipment can be used in a floating mode or sitting on the peatland surface and can extract peat from deposits up to 5 m in depth;
- the machinery appears well-suited to the cutting and pumping of certain peats;
- the equipment is adaptable from very wet (floating) conditions to drier locations;
- it could be possible to mount a light crane on the dredge for cleaning loose stumps, roots or other debris floating in the mining area.

Other than mention by the manufacturer of sporadic use in peat or peaty materials, the equipment has not been used in a continuous peat mining application. Although it is recommended that consideration be given to small scale peat mining applications, it is possible that the function of the cutter could be affected by stumps and roots. It is expected that the equipment could be modified, specifically the cutterhead, since there is considerable experience in the use of cutterheads on larger applications. It is possible that with the cutterhead operating under water and disturbing the peat deposit by the cutting action that the smaller particles will float, larger particles will settle, and in the area of turbulence surrounding the cutterhead will be mainly mid-sized particles with much of the loose peat floating throughout the mining area uncontrolled. If this occurs, the slurry pump will not discharge a mixed peat slurry but will pump mainly water and a very low % solids.

An hydraulic cutterhead dredging - slurry pipeline - solar drying operation has been reported to have operated successfully producing horticultural peat in Louisiana, U.S., (Markman Peat Company) although it is understood to have produced a low % solids peat slurry. Considering that the peat was used for horticultural use, the low solids content is not as important, however, for fuel purposes the solids content is an important factor since it is directly related to production quantities and costs.

323 COMPARISON OF SMALL-SCALE WET PEAT MINING METHODS FOR UNDRAINED PEATLANDS

.1 Bulk Peat Excavation by Amphidredge

The proposed bulk peat excavation by Amphidredge - peat slurry preparation (maceration) - pipeline transport to process plant system, to our knowledge, has never been used. However, it is closely related to an existing barge-mounted hydraulic backhoe - slurry pipeline - dewatering plant operation which has been successfully producing dried horticultural peat in British Columbia, Canada. The proposed method offers the following:

ADVANTAGES

- a) It satisfies the technical requirements of excavating peat and processing and pumping of the peat slurry by:
 - preparation of a 2.8% (by weight) solids concentration peat slurry which will ensure good production performance (e.g. maximum capacity of peat slurry suction pump, optimum distance of single stage pumping and maximum recovery from each cubic meter of in-situ raw peat);
 - preparation of a well mixed and macerated peat slurry within the specially designed peat slurry pump which will ensure an efficient energy requirement for pipeline transportation of the peat slurry and delivery of a relatively homogeneous and uniform feedstock to the process plant;
 - maximum peat recovery from deposits with depths from 1 to 5.5 m;
 - excavation of the full depth at one pass;
 - no working face collapse problems during mining operations;
 - minimum area of mining of disturbance; and
 - little pre-production drainage activities, if any.

b) Furthermore, the Amphidredge-style equipment appears to offer the following favourable characteristics:

- can carry out peat excavation in undrained peatland;
- can be used on both small and large deposits and can move from place to place easily (i.e. has flexibility and maneuverability);
- can transport itself across peatland from dry terrain into undrained peatland;
- using hydraulic legs the equipment can steady itself on the bottom of the excavated deposit in water up to 4.2 m deep (although bottom conditions must be considered);
- can navigate (float) in a minimal depth of water, about 1 m;
- can tow any other barges (e.g. split bottom) across peatland to the work location;
- the equipment can be used for other purposes (e.g. construct reservoirs, drainage channels);
- one set of equipment can produce about 50,000 tonnes of air-dried peat (50% m.c.) in a production season;
- an extended mining season, about 260 days average, or until average daily temperatures are less than 5-10 degrees C, i.e. onset of the freezing season;
- the Amphidredge appears to be a relatively simple piece of equipment, apparently easy to operate and maintain and has been used for many years overseas (including tropical locations) for small-scale dredging activities; and
- minimal operating personnel required.

c) The proposed bulk peat mining system requires minimal pre-production activity and allows production to commence almost immediately, which obviously has a favourable effect on costs (pre-production activities can be in the order of 30% of total capital costs).

d) The method can be used on any type of bog varying in degree of decomposition but not less than 15% and with an ash content up to 23%.

e) It is possible to make projected design calculations for the system based on the type of peat and its characteristics and experience with the pumping technology used.

- f) The equipment components of the proposed system are in use and currently available and it is relatively easy to assemble reliable cost information for the operation of the system as compared to other more conceptual wet peat mining methods proposed.
- g) It is possible to effectively use automatic controls on the pumping system.
- h) The proposed method is specifically advantageous in peatland areas where road building is difficult; electrical lines and water electrical lines and water supply system is not required.
- i) Reclamation can follow quickly, i.e. it does not have to wait until mining activities have ceased, or have been completed. The mined area can be reclaimed for agricultural, silvicultural, small scale fishery or recreational use.
- j) The proposed method causes little, if any, damage to adjacent lands.

DISADVANTAGES

- a) Peat losses are more difficult to control during excavation, since depth control is difficult in the slurry pond especially when the water level is high. Also current depth control methods are visual.
- b) Storage of sufficient peat slurry during the freezing season.
- c) A higher level of detail on the peat characteristics throughout the deposit is required to maintain acceptable peat slurry quality during production.
- d) Some overflow could result when rain and water has to be re-directed.
- e) A special barge or Amphidredge will have to be constructed for mounting of the separator, tanks and slurry pump.
- f) Some experimentation is required to test equipment performance in the field.

.2 Small-Scale Milling Cutterhead Suction Dredge

ADVANTAGES

- a) Excavation can be performed on undrained peat deposits up to 5 m deep.
- b) All types of bogs can be excavated.
- c) The peat slurry can be pipelined directly to the process plant (nearby) without the need for intermediate tanks. Slurry pipeline systems have many years of experience.
- d) The cutterhead can operate even under conditions of high stumps and roots content.
- e) All equipment is on a single dredge. No requirement for barges to transport stumps, roots, etc.
- f) Equipment costs are less than the bulk excavation by Amphidredge method. The equipment is readily available.
- g) Maneuverability of the equipment is good, e.g. from dry land to wet peatland & vice versa.
- h) The equipment can be used for mining small deposits and is easy to move and transport to another bog location.
- i) This system operates continuously when excavating versus the intermittent operation of the backhoe or clamshell equipment.
- j) Minimum personnel requirement.
- k) The system is economical; i.e. electrical lines and water supply are not required.
- l) The impact of on-going mining is confined to a relatively small area.
- m) The mining season is lengthened to about 260 days per year versus other methods.
- n) The mined area can be reclaimed after use for agriculture, silviculture or recreational use. The impact on the surrounding terrain by the dredging system is minimal.

DISADVANTAGES

- a) Our calculations show that the solids content in the peat slurry using this method will be about 1%, versus about 2.8% using the bulk excavation method. Consequently, the yield of dry matter per cubic meter of mined peat slurry will be reduced in the former case.

- b) High peat mining losses are expected during excavation due to peat particles dispersed by the cutterhead action which are expected to float in suspension throughout the slurry pond.
- c) It is expected that considerable equipment downtime may be experienced by blockage of the suction pump by pieces of stumps and other debris cut up by the cutterhead.
- d) For best performance on peat, specially-constructed equipment for suction, cutting and pumping of the peat slurry should be used.
- e) Other disadvantages mentioned for the bulk excavation system will be applicable to the cutterhead dredge method (e.g. level of detail of peat surveys, overflow after heavy rainfall, peat slurry storage, etc.).

3.3 MEDIUM SCALE OPERATIONS

For purposes of this study, medium scale wet peat mining operations have been considered to be about 250,000 to 500,000 tonnes of fuel peat per year (at 50% moisture content equivalent). Calculations show, for the 250,000 tonnes per year production level, that a single peat deposit of about 3200 ha averaging 2.25 m deep and yielding 45-50 million cubic meters of recoverable peat would be required, taking into consideration mining losses. Two different systems have been considered for this scale of wet mining operation, (a) the Bucket Ladder Dredge and (b) the Hover Barge with Backhoe Excavator.

331 BUCKET LADDER DREDGE-CONVEYOR-PROCESS PLANT

This concept is a slurry pond method. This term is used throughout the literature to describe methods whereby mechanical excavators or dredges are floated on a pond within the bog, and are used to cut the peat which is then transported to a dewatering site. Peat is excavated by a floating bucket ladder dredge. The dredge has a single continuous chain of buckets which rotate over rollers located at each end of the ladder. Peat is scooped up by the buckets at the lower end of the ladder and then dumped into chutes or onto conveyors when the loaded buckets rotate over the top roller. The excavated peat can then be conveyed by belt to the dewatering plant.

ADVANTAGES

- a) Bucket ladder dredges can be expected to remove the peat at a significantly higher percentage of solids.
- b) Little pre-production site preparation is required. Bog drainage is not required.
- c) The full thickness of peat can be removed in a single pass.

- d) The bucket design is well-suited for excavating highly decomposed peat.
- e) A smooth, bottom contour can be more easily maintained than with some other methods.
- f) Larger and heavier machinery can be used than on even a prepared bog surface, due to the fact that the equipment is floating in a dredge pond.
- g) No slope failure problems.
- h) It is expected that the system will be more economical than other mining systems requiring power lines to supply electricity to the site.
- i) This method causes mixing of all peat layers, thus producing a uniform quality of peat produced.
- j) No drainage of the peatland is required.
- k) The proposed method causes little, if any, damage to adjacent lands.
- l) It is expected that equipment components could be obtained or fabricated in North America.

DISADVANTAGES

- a) A specially designed bucket dredge is required. Conventional bucket ladder dredges excavate a relatively narrow trench beneath and in front of the dredge, and are best suited for excavating free flowing materials. The dredge would probably have to be redesigned with wider buckets to excavate peat.
- b) Bucket ladder dredges are more expensive to purchase than other dredge systems of similar capacity.
- c) Bucket ladder dredges require well planned preventative maintenance. Breakdowns are generally more prevalent.
- d) A continuous, extensible, partially floating conveyor system would be required. Conveying wet, soupy peat is questionable especially during cold (below 0 degrees C) weather because the peat may freeze to conveyors, hoppers, chutes, etc. A conveying system would have to be developed and the harvesting season with the onset of cold weather may have to be shortened.
- e) Bucket ladder dredges generally have a deeper draft than other dredge systems of similar capacity. The ladder assembly (ladder, buckets, chain and tumblers) is heavier than in other dredge systems, which in turn necessitates a more substantial A-frame and hull. Therefore, the minimum depth of harvestable peat increases

and some reserves are lost, or a larger hull must be constructed to reduce draft.

- f) Water from the process plant would have to be returned to the dredge pond, unless large quantities of make-up water are available.
- g) A suitable large capacity bucket ladder dredge could not be identified as being currently commercially manufactured.
- h) Some peat loss expected during excavation connected with the method of controlling depth of cut and with unevenness of bottom.
- i) A separator may be required at the process plant to separate stumps, roots and bulk mass.
- j) Problems with excess water after periods of heavy rainfall, since it will be necessary to control the water level for the mining operation.
- k) Peat slurry storage is required for the freezing season.
- l) Tests will be required to determine how effectively the system operates for mining undrained peatland.

332 SLURRY HOVER BARGE WITH BACKHOE EXCAVATOR

This type of operation has been described in some detail in Section 124 of the report. This system can be used on undrained peatlands for small and medium scale operations. This system is in operation at Fisons-Western Inc. in British Columbia and produces about 30,000 tonnes (air-dried peat, 50% moisture content). Both the advantages and disadvantages of the system as currently used are discussed.

ADVANTAGES

- a) This mining method is influenced very little by weather and can be used over most of the year.
- b) All the production equipment is on a single barge.
- c) The air-cushion barge allows movement over uneven peatland both over land or water.
- d) Can be used on peatlands with a large percentage of stumps and roots since the equipment includes a separator system.
- e) The full thickness of peat is excavated in one pass.
- f) Mixing of the peat in the peat slurry holding tank provides a more uniform quality.

- g) Compared to other methods, the hoverbarge system is compact and self-contained, therefore production control and maintenance is simplified.
- h) Manpower requirements are small, 3 or 4 men per shift.
- i) Pre-production and development costs are low since the drainage ditch network and associated engineering is not needed.
- j) All power is from on-board diesels, no power lines are required.
- k) Equipment is available in North America.
- l) Little damage to the environment and reclamation can proceed early. The mining activities are confined to a relatively small area.
- m) Good cost information exists on this system in terms of operating and capital costs.
- n) The proposed method causes little, if any, damage to adjacent lands.

DISADVANTAGES

- a) The low percent solids experienced in the peat slurry limits peat production from the slurry pump/pipeline system. It is important to control the percent solids in the peat slurry and a major factor is the water addition in peat slurry preparation. Although control of % solids can be affected by measuring the weight of dry material present in a peat slurry sample other methods to determine solids content are mentioned in Section 2.3.3.
- b) A specially constructed peat slurry pump is required which will cut, grind and macerate the peat fibers, small rootlets and pieces of stumps.
- c) This method produces some peat losses during excavation of the peat and peat slurry storage and processing.
- d) A considerable amount of the hover equipment is used only intermittently.
- e) It is recommended that this method be considered for further development work to improve the solids content of the peat slurry pumped from the mining area.

3.4 SELECTION OF MINING METHODS FOR UNDRAINED PEATLAND

In Section 2, various factors of importance in the selection and evaluation of alternative wet peat mining methods were discussed. Final selection of most suitable methods for both undrained and drained peatlands considered the following mining and feedstock requirements:

- mining: peat quality characteristics (peat type, size of deposit, moisture content, peat depth, degree of decomposition, ash content, stumps content),
- feedstock: quality of the peat slurry as a feedstock to the process plant (optimum solids content, maximum pumping capacity, minimum pipeline pressure losses, high quality slurry preparation characteristics).

The following general criteria were used to select and rank the various mining methods:

- peat type conditions: the selected mining and transport system must be compatible with the physical and chemical characteristics of the peat deposit in supplying peat feedstock to the process plant
- production requirements: the selected mining and transport system must be capable of producing the required amount of fuel peat feedstock to the process plant for the duration of the plant life at a given yearly production rate regardless of conditions
- economics: the preferred mining/transport scheme must supply the feedstock in a cost effective manner
- environmental impacts: the preferred mining and transport system must minimize adverse environmental impacts.

A numerical evaluation system was applied to each wet mining method concept. Each of fifteen evaluation criteria could contribute a maximum of five points to a mining concept's ranking score. A listing and description of the main selection criteria used for the analysis is given below in Table 3-3. The highest possible score was 66 or 100%. Results from the evaluation are on Table 3-4 which, for the case of the undrained peatland, shows the bulk peat excavation by Amphidredge ranked highest.

3.5 RECOMMENDATIONS FOR FURTHER STUDY AND TESTING

Table 3-4 shows that, according to the analysis, the best method for wet peat mining on undrained peatland is the bulk peat excavation by Amphidredge method. Further detailed engineering and field testing is required to accurately establish outputs, system economics and best equipment selection. It is recommended that a fuel peat deposit with the following characteristics be considered for test purposes:

- degree of decomposition not less than 15%;
- average depth not less than 1.5 m, and
- ash content no greater than 23% (dry basis).

It is suggested that a wet peat mining test program be undertaken which would include:

- A) further engineering design and calculations to establish realistic working conditions and calculations for final equipment selection and possible re-design and/or modifications, including:
- design and testing of a special peat slurry pump (incorporating cutting, grinding and macerating characteristics) and further determinations of the rheology of peat slurries from various Canadian peats.
 - selection and sizing of a high pressure water system and control methods (e.g. for sprays, water additions, etc.).
 - determination of the output of an equipment set in cubic meters of raw peat excavated and cubic meters of slurry produced, correlated to the characteristics of raw peat input.
 - determination of the practical production of final peat product per cubic meter of peat slurry and analysis of process losses including the mining and slurry preparation losses.
- b) determination of equipment downtime (efficiency).
- c) establish length of mining season.
- d) establish peat bog resource quantities and mining production losses taking into consideration peat depth, stumps content, and weather conditions (including freezing).
- e) testing of floating pipeline system.

- f) determination of abrasivity and corrosion characteristics of the the peat slurry.
- g) evaluation of environmental impact of mining operations.
- h) detailed determination of capital and operating costs associated with the bulk peat excavation by Amphidredge method including slurry preparation and pumping system.

Table 3-4 Main Selection Criteria
(Ranking Factors)

No.	Description	Weight
1	Peat deposit moisture content and depth of raw peat (for maximum capacity of mining equipment)	5
2	Peat quality characteristics (degree of humification, ash content, peat slurry solids content)	5
3	Peat feedstock quality processing requirements (cutting, grinding, maceration)	5
4	Effect of meteorological factors on length of mining season	5
5	Pre-production activities (requirements - amount of work clearing of trees and bushes, drainage system, etc)	5
6	Most economical transport system	5
7	Use of existing mining and transport equipment to achieve production capacity and minimum manpower requirements	5
8	Existing knowledge concerning mining and transport systems design (technology, methods of calculating the basic industrial and technical indexes)	5
9	Possibility of separation of stumps, roots, sphagnum moss during mining operations	4
10	Minimum losses of peat	4
11	Availability of electrical energy and water supply sources	4
12	Possibilities of generating revenues from the reclaimed peat mining area (e.g. possible use for agriculture, forestry, fishery)	4
13	Minimum adverse environmental impacts	4
14	Availability of information on capital and operating costs, and prices of mining and transport equipment	3
15	Compatibility of peat bog mining equipment capacity and peat processing plant equipment capacity	3

Table 3-5 Results of Ranking for Wet Mining Methods on Undrained Peatland

UNDRAINED BOG					
SMALL SCALE			MEDIUM SCALE		
Selection Criteria No.	Weight	Bulk Peat Excavation by Amphidredge	Milling Cutter Suction Dredge (Amphidredge)	Bucket Ladder Dredge	Slurry Hover Barge with Backhoe Excavator
1	5	4	4	4	4
2	5	5	2	4	2
3	5	4	2	2	4
4	5	4	4	4	4
5	5	5	5	5	3
6	5	5	5	2	5
7	5	4	4	3	5
8	5	5	3	3	5
9	4	3	0	0	3
10	4	3	3	3	3
11	4	4	4	4	3
12	4	4	4	4	4
13	4	4	4	4	3
14	3	3	2	2	3
15	3	3	2	2	3
=====					
TOTAL:	66	60	48	46	54
=====					
%	100.0	0.91	0.73	0.70	0.82
=====					

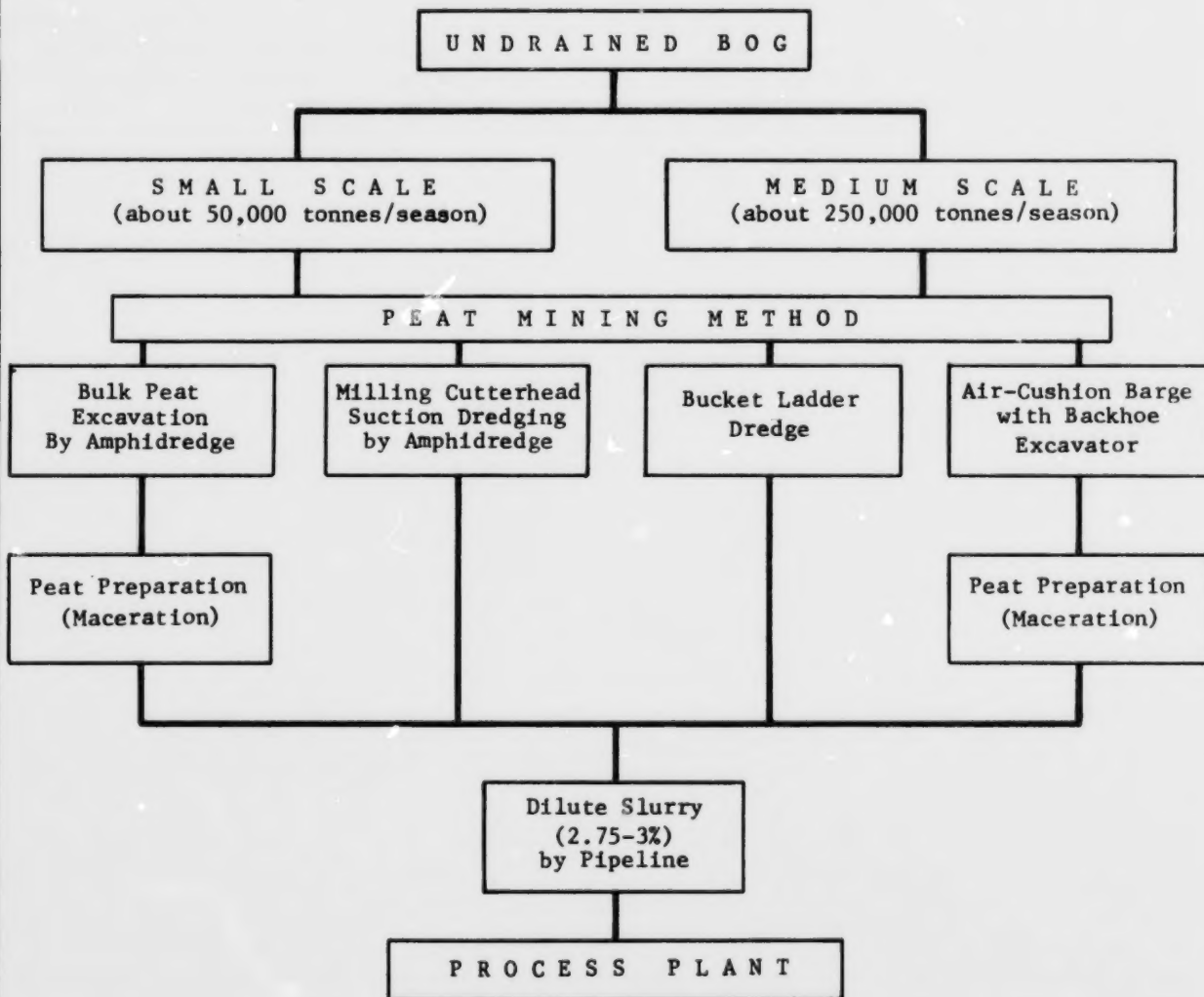


FIG. 3-1

NATIONAL RESEARCH COUNCIL

EVALUATION OF ALTERNATIVE
WET PEAT MINING SYSTEMS

**PROPOSED WET PEAT MINING
ALTERNATIVES FOR UNDRAINED BOGS**

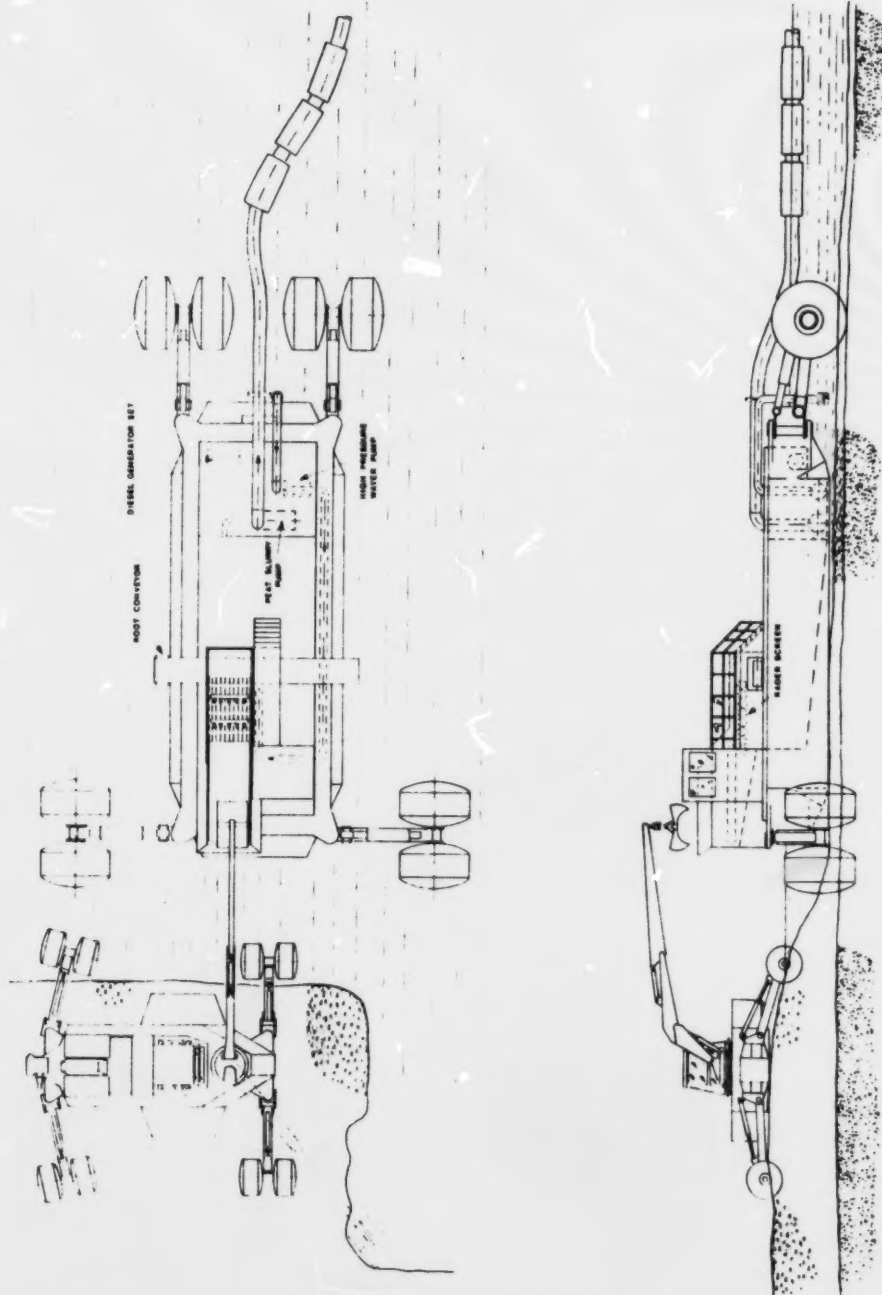
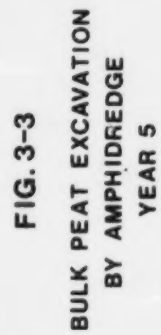


FIG. 3-2
 NATIONAL RESEARCH COUNCIL
 EVALUATION OF ALTERNATIVE
 WET PEAT MINING SYSTEMS
 GENERAL ARRANGEMENT
 OF BULK PEAT EXCAVATION
 BY AMPHIDREDGE



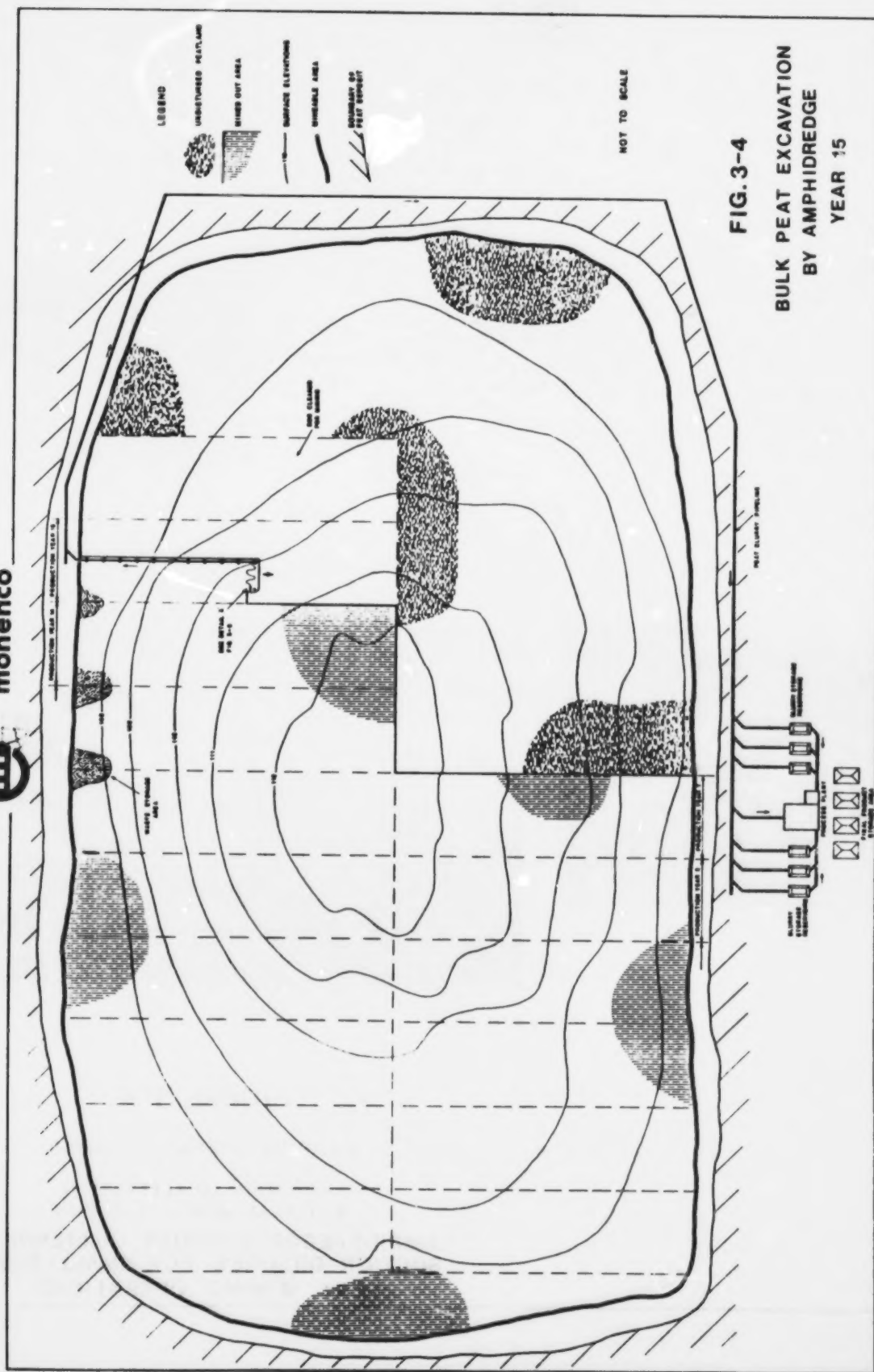


FIG.3-4
BULK PEAT EXCAVATION
BY AMPHIDREGE
YEAR 15

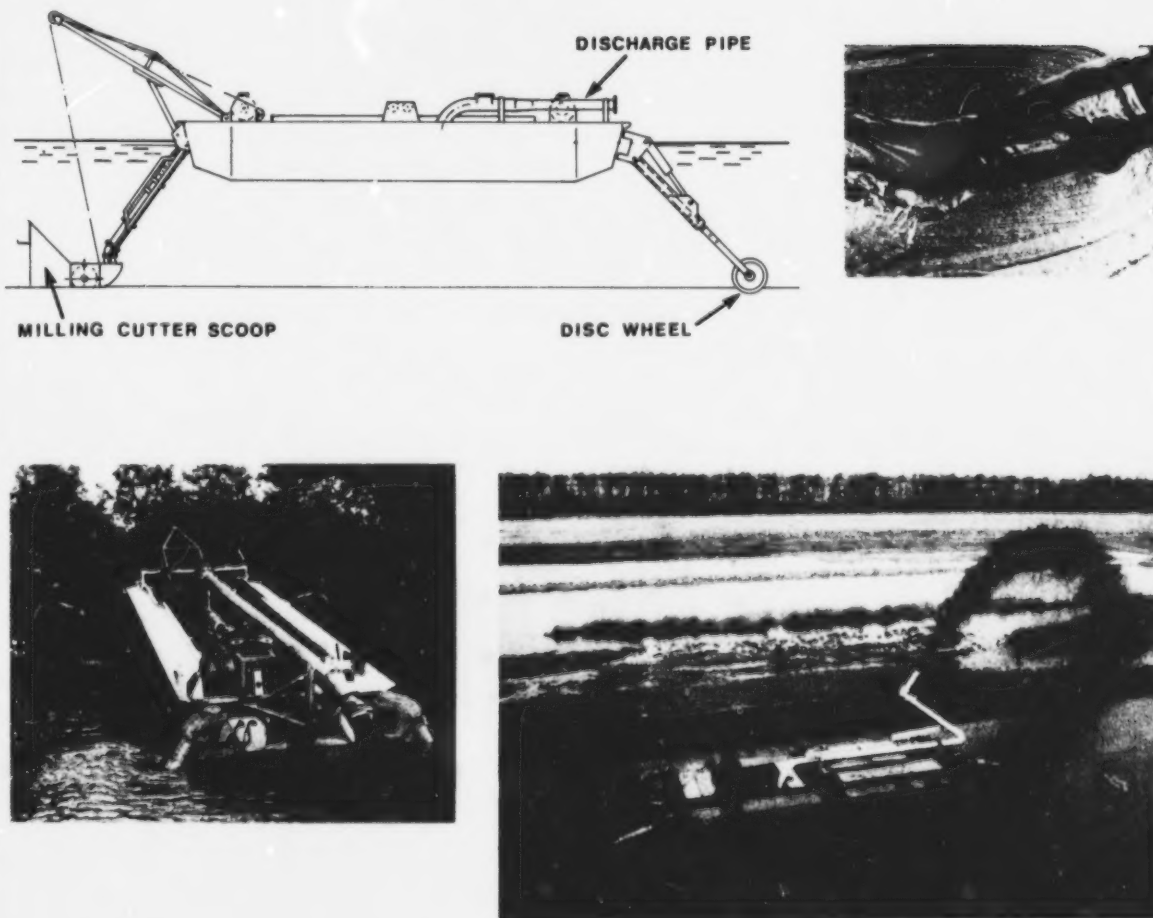


FIGURE 3-5

NATIONAL RESEARCH COUNCIL

**EVALUATION OF ALTERNATIVE
WET PEAT MINING SYSTEMS**

**AMPHIDREDGE S-SERIES CUTTERHEAD
SUCTION DREDGES FOR SMALL-SCALE
PEAT MINING OPERATIONS**

PART 4

WET MINING OF DRAINED PEATLANDS

PART 4 - WET MINING OF DRAINED PEATLANDS

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4.0 WET MINING OF DRAINED PEATLANDS

4.1 INTRODUCTION

This chapter contains information on wet mining methods proposed for drained peatlands for medium and large scale applications (see Figure 4-1). By the term "drained peatlands", all types of peatlands are considered (lowmoor, highmoor, transitional) which after drainage allows the trafficability of the various peat mining machinery without the risk of collapse of the bog surface. Excess water from the peat deposit is drained (subject to certain environmental constraints) to nearby streams or peatlands assisted by a network of open or closed drains. If the drainage channels operate effectively, then all excess surface water occurring during operations is quickly discharged from the mining area. It is important to maintain the water table below the surface between the drainage ditches to keep the moisture level in the surface layer of peat at the required levels. If the drainage system operates well, production losses from the mining operations will be minimized (e.g. an effective drainage system will ensure minimum sized dikes, good control on bottom losses, etc).

If the moisture content in the top layer of the peat deposit is lowered, the temperature of the top layer will be higher. Experience in the summer period on drained peatlands shows that the temperature can be 2-7 degrees C warmer than if the layer were undrained. Generally, moisture reduction enhances the production of peat. For every % reduction in moisture in the top layer, the production of mined peat will be 7-8% higher (in terms of air-dried peat, 35% moisture content).

Table 3-1 described the characteristics of various Canadian peats. Deposits with the same general characteristics are also considered in this Section, except that the moisture of the raw peat, after drainage, is taken as averaging 98.5% in the portion of the deposit being mined.

4.2 MEDIUM SCALE OPERATIONS

For purposes of this study, medium-scale operations are considered to be about 250,000 tonnes of air-dried peat (50% moisture content) per year. To have an annual production at this rate for 25 years, it is estimated that 52 million cubic meters of raw peat is required equivalent to about a 3200 ha peatland with an average depth of about 2.25 m, allowing for losses for the systems considered.

Two methods of peat mining have been selected for analysis for medium scale operations on drained peatlands, including:

- a) the Bucket Excavator or Bagger system, and
- b) Bulk Peat Excavation.

Little attention has been given in previous North American investigations of fuel peat mining methods to the possible merits of the bucket excavator or Bagger system. The Bagger system is composed of the excavator and associated spreader machine which is designed to excavate, "process" and spread peat sods over a drying field to dry. After the excavator, a certain amount of "processing" of the peat is carried out prior to spreading. The peat at this stage is about 10-12% solids content and of quite uniform characteristics. Provided the peat can be transported economically off the fields at this point, there are a number of peat processing systems under development which claim to accept a 10% solids by weight, raw peat feedstock.

Statistics taken over a long period in the U.S.S.R. have shown that the practical yield (in tonnes of air-dried 33% moisture content peat per cubic meter of raw peat), comparing various mining methods employed, is highest for the Bagger system (see Table 4-1). The Bagger system is also used for peat production in Ireland (originally based on German bagger equipment) to provide fuel peat for power generation and other uses. For the above reasons it was decided to include the Bagger system.

Table 4-1 Practical Yield by Different Peat Mining Methods

Mining Method	(tonnes air-dried peat, 33% m.c. from 1 cubic meter raw peat)
=====	=====
Milling	0.115-0.170
Hydropeat	0.130-0.190
Bucket Excavator (Bagger)	0.150-0.225

421 BUCKET EXCAVATOR (OR BAGGER) SYSTEM

In order to successfully implement the Bagger system, the following peatland conditions are required:

- a) a minimum average degree of decomposition of peat of 15%, over the excavated depth,
- b) a minimum average depth of the mining area of 1.5 m in the undrained state,
- c) maximum depth of excavation for drained peatland of 4.25 m and
- d) a maximum ash content of 23% (dry basis).

The basic design considerations for deployment of Bagger equipment are:

- maximum length of pit,
- a suitable drainage system, and
- maximum peat recovery.

A detailed mining plan must be developed to suit the individual peatland characteristics.

Figure 4-2 shows a picture of a Bagger excavator used for excavating many types of peat and under varying conditions of stumps content. Bagger excavators are also made with separators for removing stumps (see Figure 2-5), up to a stumps content of 3%.

The bucket excavator usually has either a hammer mill or peat press which is used to cut, press and extrude the raw peat. This equipment is important to produce the desired properties in the peat feedstock. Selection of the most appropriate processing device at a particular location depends on peat type, degree of decomposition, moisture content of the excavated material and other physical characteristics of the peat.

Figure 4-3 shows the mechanical parts of the peat press and peat hammer mill. The peat press cuts the raw peat using two types of knives: rotating sets and stationary sets. Of various peat presses available, the preferred model gives the highest number of cutting blows per cubic meter of peat (e.g. in excess of 3500 cutting blows per cubic meter). The moisture content of the raw peat to the press is an important factor. For example, with a lowmoor peat with moisture content less than 84%, it is necessary to add water to avoid problems with the press.

The "processed" peat from the bucket excavator system can be loaded onto a conveyor or bulk carrier (about 7 cubic meters) for transport from the bog to the process plant. Figure 4-4 shows the placement of the Bagger-type excavator on the bog surface. The bagger ladder turns with the upper platform through 65 degrees cutting the peat to depth at a slope, and after every cut the excavator is moved forward a little distance. The distance moved depends on the depth of excavation and the quantity of peat required to fill the buckets. The pit width can be changed to accommodate differences in peat depths and to avoid excavating basal material.

Calculations show that on a peatland of about 3200 ha. (about 50-55 million cubic meters) four Bagger equipment sets are required (equivalent to the model shown in Figure 4-1) which can produce 270,000 to 280,000 tonnes annually of air-dried (50% moisture content) peat (25 year mine life). The seasonal production of a single Bagger equipment set is about 70,000 air-dried (50% m.c.) tonnes.

The following are expected to be typical operating characteristics for a Bagger system fuel peat operation in Canadian conditions:

- transitional-type peat deposit,
- degree of decomposition - 27%,
- average peat depth - 2.25 m,
- average moss peat layer - 0.25 m,
- average moisture of deposit - 91.5%,
- average moisture after drainage - 88.5%,
- production air-dried (50% moisture content) peat from 1 cubic meter of raw peat after drainage - 0.16 tonnes,
- bog subsidence coefficient after drainage - 0.82,
- compression of peat during pressing - 0.93,
- density coefficient of pressed peat - 0.99,
- overall peat recovery from the working pits - 0.91,
- hourly rated capacity of the bucket ladder mechanism - 106 cubic meters of raw peat. Included in this calculation is:
 - speed of bucket chain (stumps content 1.5%) - 0.406 m/sec.,

- capacity of a single bucket 0.13 cubic meters,
- bucket fill factor 1.0, and
- peat excavator load factor 1.3.
- utilization factor of equipment (at stumps content of 1.5%) - 0.76,
- shifts per 24 hours: 3 shifts, 8 hours per shift (1 hour per shift for maintenance and moves),
- mining season - 260 days.

Transport of the mined peat product is not included in this section since it is discussed separately in Section 5.

422 BULK PEAT EXCAVATION

Currently, bulk peat excavation is not common in large projects, but backhoes, clams and draglines have all been used for peat excavation on a localized basis, or for ditching. The equipment descriptions that follow are based mostly on knowledge of this type of activity and on manufacturers' handbooks for estimating equipment output.

Most common excavators are the backhoe, front shovel, clam or dragline. These devices can be mounted on a barge, for working in water-filled excavations or on a tracked or wheeled chassis. For work involving travel over the peatland surface, the tracked chassis is necessary and not all of the various machines available are light enough for this purpose. Only the lightest backhoes on long, wide tracks can be used in this manner, and even then their mobility is marginal. The remaining machines have to be barge-mounted or work from timber pads which can be swung into position by the excavator itself.

Successful bulk peat excavation operations on peatland depends on a number of factors. First, development (preparation) of the peatland before excavating must take the capabilities and limitations of the excavating equipment into account; draining the peatland probably prevents the use of most barge-mounted excavators. After drainage work is completed, some time (several months, or even years) will have to be allowed to pass before the peatland will support the weight of the excavators. This will be especially true if the surface vegetation is disturbed or removed.

The mobility limitations and design features of the excavators must be integrated with those of the surface transport system so that the excavated peat can be successfully loaded for transport. Even though the excavator is not required to travel at high speed or for long distances at a time, mobility is still important. Several potential problems exist; the weight and ground pressure of tracked excavators are high enough to prevent them from travelling directly on the surface of many undrained peatlands without being immobilized. Even on partially drained peatland, the lightest of the machines can travel if they keep moving, but when standing long enough to excavate all the peat they can reach, they can sink to the point where they are immobilized when the operators try to move to the next digging position.

By using timber pads under the excavators, the problem can be diminished. For example, a Caterpillar 215 excavator has a working weight of 17,280 kg and a ground pressure of 0.41 kg/sq. cm. with the widest available tracks. The values are low enough for working on well drained peatland in dry weather, but too high for undrained or partly drained peatland. A six-inch timber pad (4.8 x 3.4 m) under the excavator would increase the weight to about 19,960 kg but decrease the ground pressure to about 0.12 kg/sq. cm. The excavator could probably then work on a partly drained peatland, provided it moved at least once every two hours, but should not be parked overnight on the peatland.

The final hazard of working on pads is that the bearing capacity of the peatland surface can vary from place to place, so that a pad may not have uniform support beneath it. This, combined with the motion of the excavator's centre of gravity as it is working, could result in tipping or upset of the excavator. Operator experience would be an important factor in avoiding this type of accident.

When using barge-mounted excavators, the peat being dug would be very wet, and not likely to stick in the excavator bucket. Drier peat, on partly drained peatland, can become lodged in the bucket, significantly reducing the output of the excavator. This problem can be minimized by using buckets especially designed for digging peat, such as the Finnish buckets used for digging drainage ditches in peatland.

423 COMPARISON OF MEDIUM SCALE METHODS

.1 Bucket Excavator (Bagger System)-Surface Transport-Process Plant

This method is similar to traditional sod peat harvesting except that macerated peat is transported directly from the "Bucket Excavator" using several transport modes directly to the process plant.

ADVANTAGES

- a) The Bucket Excavator "Bagger" machines have been used in Europe to harvest fuel peat for decades.
- b) The "processed" peat after the peat press gives a good quality feedstock for further peat processing, e.g. solids content 10-12%, uniform quality of mined peat achieved since the excavator cuts through all the peat layers of the deposit and mixes the peat well, and since the peat press provides sufficient cutting and pressing of the raw peat.
- c) Maximum recovery of the minable peat within the deposit (no drying areas are required).
- d) The Bagger method can be used for all peat deposits with a degree of decomposition greater than 15%, a minimum peat depth of 1.5 m and an ash content less than 23% (dry basis).
- e) Varying cut widths can be used, depending on depth of deposit, up to a maximum of 12.5 m. Maximum depth is 4.25 m.
- f) Can excavate peat with stumps content up to 3% by volume, and can separate stumps, roots, etc. from the peat.
- g) Minimal danger from slope failure.
- h) Bagger equipment is readily available.
- i) One Bagger machine has a capacity of about 68,000 to 70,000 tonnes per mining season of air-dried peat (50% moisture content).
- j) Technical expertise and experience is available to design Bagger systems based on a knowledge of the characteristics of the peat. Cost information can also be obtained.
- k) Minimal dependency of the mining season (about 260 days per year) on meteorological factors.
- l) The bucket excavator can load peat directly into trucks, tractor pulled wagons, railroad cars, or onto conveyor belts for direct transport to the process plant.
- m) The bucket excavator operation is a single pass method, assuming adequate ladder length is available.
- n) Two operators per Bagger excavator are required.
- o) The drainage system carries all run-off away effectively.
- p) The peatland can be reclaimed for agriculture, silviculture, fishery, etc.

DISADVANTAGES

- a) The total mining area must be drained and considerable pre-production bog preparation is required.
- b) It can take 2-3 years before production commences.
- c) Storage of mined peat is required during the freezing period.
- d) A mining depth limitation of about 4.25 m.
- e) Certain Bagger equipment would possibly require adaptation to Canadian conditions and training for local operators.
- f) More detailed investigation is required to select the most appropriate transport system for haulage of the mined peat product to the process plant.

.2 Bulk Peat Excavation

ADVANTAGES

- a) This method can be used on all peat deposits with a degree of decomposition greater than 15%, a minimum depth of undrained peat of 1 m, and an ash content less than 23% (dry basis).
- b) The feedstock to the process plant will have a high solids content.
- c) Small, shallow deposits can be mined.
- d) The full thickness of peat can be excavated in a single pass.
- e) The bulk peat method can be used with trucks, tractor-pulled wagons, railcars, or conveyors for direct transport to the process plant.
- f) Equipment is readily available in North America.
- g) Good drainage of the water after rains is possible (e.g. drainage system in place).
- h) Minimum impact on adjacent peatlands. Peatland can be reclaimed for agriculture, silviculture, fisheries, etc.

DISADVANTAGES

- a) Considerable pre-production site preparation is required. Site preparation can take 2-3 years (e.g. ditching, clearing, etc.).
- b) This method does not include mixing of the peat layers (nor cutting and pressing to produce a uniform quality product).
- c) No separation or pressing equipment has been developed for the equipment to separate roots or stumps, etc. during the mining operation.
- d) It is recommended that extensive testing be carried out before implementing this system.

4.3 LARGE SCALE OPERATIONS

431 INTRODUCTION

For purposes of this study, large scale peat operations are considered to be up to 1 million tonnes/year of air-dried (50% moisture content) peat. Calculations show that to achieve a 25 year mine life at the above annual production rate, about 220 million cubic meters of raw peat is required, equivalent to about a 7000 ha bog with an average peat depth of 4 m, considering losses. The following methods have been selected for further evaluation, for large scale operations:

- slurry pump dredge system, and the
- hydro-settling method by slurry pump dredge (Monenco Method).

The slurry pump dredge system proposed is similar to the hydropeat method since it is based on hydromonitors (high pressure water jets) to break up the peat deposit and transform the peat into a liquid slurry. However, this system has special technology which makes it unique which will be explained further in this Part. In Part 1, it was noted that the hydropeat method was used in the U.S.S.R. for over 40 years and its use after 1960 decreased rapidly to be completely replaced by the more economical milled peat method. This decision was made after evaluation of the following disadvantages of the method:

a) Mining Operation

- Large manpower requirement for operating and equipment moves; considerable amount of manual labour involved. A set of New Standard (N.S.) equipment required 27 men and a set of Super Standard (S.S.) equipment required 45 men.
- Downtime was excessive since the stump clearing operation for the working pit area was often incomplete and considerable manual labour was often required to rid the working pit of stumps and other debris.
- A pile foundation was required for the slurry crane and high pressure water station.
- Risk of failure of the mining face was high when the depth of the peat deposit exceeded 4 m.
- It was required to constantly move the hydromonitors by hand and also the high pressure water lines to the monitors during mining operations.
- A limited mining season, about 90-100 days per year.

b) Peat Drying Operation

- Large areas were required for drying the peat slurry.
- Time consuming method for spreading the peat slurry over the drying area (connecting and disconnecting a large piping network), also poorly mechanized and requiring large amount of manual labour, e.g. one set of New Standard equipment required 39 men for the slurry spreading process and 90 men for the Super Standard set.
- Considerable amount of metal, e.g. piping system, was required.
- Also, with the harvesting equipment, a considerable number of workers were required, e.g. for the harvesting operation, 5-6 men were required for each 1,000 tonnes seasonal capacity of air-dried peat.
- Seasonal field drying, about 4 months per year.

432 SLURRY PUMP DREDGE SYSTEM

Figure 4-5 shows the general layout of the slurry pump dredge equipment in operating position. All the equipment is mounted on an air cushion barge approximately 10m x 10m with a payload capacity of 50 tonnes. The following equipment is placed on the air cushion barge:

- special mining peat slurry pump which pumps the peat slurry from the mining site directly to the process plant or via a booster pump or an intermediate slurry reservoir,
- slurry pump hoist,
- stump extraction crane,
- high pressure water pump,
- hydromonitors,
- cab for hydromonitor operator,
- a section of slurry pipeline, air evacuation valve and,
- a section of the water pipeline for the high pressure water pump.

Figure 4-6 shows the general arrangement of the slurry pump dredge system. Water jet sprays from the hydromonitors break down the raw peat from the deposit and the air-cushion barge travels into the deposit as the peat slurry accumulates in front of the dredge. This action is as opposed to the manually operated hydromonitors used with the Hydropeat method, which are placed on the deposit in front of the slurry crane to wash the peat slurry towards the slurry crane. The range of the hydromonitors selected for preliminary calculations was 20m, however, hydromonitors are available with ranges up to about 70m.

The first stage in mining is to develop a "funnel" which is a part of the working pit and is developed by the hydromonitors. The funnel is developed to the full depth of the deposit (less about 20 cm of peat left on the bottom). The funnel is about 15m x 15m and the peat slurry from all parts of the working pit flows into the funnel where the special peat slurry pump is located. The 20 cm peat layer is left on the bottom for reclamation purposes and also to minimize contamination from the underlying mineral soil.

The second stage of mining is the formation of a trench as a continuation of the funnel. The trench has a width of 15 m and a length of about 30-60m depending on the range of the hydromonitor system. The third stage follows after the trench has been formed. It consists of washing down the raw peat from the deposit to the right and the left of the air-cushion barge by the side-mounted hydromonitors. At the same time the two front-mounted hydromonitors continue to work. The length of the working pit and the thickness of the peat layer left on the bottom is checked 2-3 times per shift. Both large and small stumps and roots are loosened by the

hydromonitors and many are carried with the peat slurry to the peat slurry pump. The small stumps, roots and other debris which flow to the peat slurry pump are repelled by the external propeller and they accumulate around the pump, forming somewhat of a "basket" and can block the flow of slurry to the pump. When this occurs the pump is raised and the long boom hydraulic crane is used to remove the stumps and other debris elsewhere. The stumps and roots can be used for making dikes and dams.

Sometimes, large stumps which do not flow with the peat slurry will lie in the pit, blocking the working area. The peat slurry flowing to the funnel has to find alternate routes around or through the stumps. Peat solids will also settle out in areas of stumps resulting in the remaining slurry becoming dilute, and affecting the output of the peat slurry pump. Other blockages can also occur. For these reasons, it is important to systematically clean the working pit area of small and large stumps as soon as they are washed out by the hydromonitor.

The clean water supply for the high pressure water pumps can be obtained from open water tributary ditches. Water flows through a water distribution channel by gravity from higher areas on the peatland and is fed to the various equipment sets. Figure 4-6 shows the air-cushion barge in the working pit (pit dimensions shown to be 30m to 60m x 170m) which is part of the seasonal pit. The seasonal slurry pipeline is placed in the center of the seasonal pit. A section of pipeline joins the seasonal slurry pipeline to the air-cushion barge in the working pit. For each equipment move the water and slurry pipelines are disconnected and connected to a point near the end of the barge.

Movement of the equipment set is by air-cushion, assisted by a winch. The timing of each move depends on the peat depth. Re-arrangement of the pipeline support members and connecting/disconnecting of the pipelines at the barge is done with the assistance of the crane mounted on the barge.

Dikes are located between seasonal pits to restrict the flow of water from one seasonal pit to another. Preliminary calculations show the dimensions of the dikes to be about 1m high and 1.6m at the bottom and about 0.6m at the top. Control of the slurry level in the working pit is required to maintain smooth operation of the pumping system, e.g. for % solids control and to keep the slurry pump submerged to avoid undue amounts of air entering the pipeline. An air evacuator system is required on the air-cushion barge to purge excess air from the pipeline.

Preliminary calculations show that the equipment sets are most economically operated in groups of two. The number of groups depends on the annual peat production requirement. A portion of the mining area is set out for each group of equipment; the area is calculated to ensure that it is sufficient for the required rate of production. The seasonal pit is divided into working pits and pit lengths are based on peat depth and equipment productivity.

433 A METHOD TO DETERMINE OPTIMAL PEAT SLURRY SOLIDS CONTENT AND MAXIMUM PUMPING DISTANCE

It has been discussed (Part 2 and Appendix 1) that a 2 km slurry pipeline length is considered near optimal for single stage peat slurry pumping by a typical mining peat slurry pump. With shallower peat depths, a greater number of mining cycles is required through the seasonal pit, or it may be necessary to locate booster pumps or intermediate peat slurry reservoirs at suitable points.

Solids content in the peat slurry can be increased to an optimal level to obtain maximum pump capacity, but beyond this point, the viscosity increases, resistance to flow increases and pump capacity begins to decrease. Solids content in the peat slurry is determined by calculations which take into account pressure loss, viscosity, flow velocity, etc. For the pressure loss (H) calculation, the Weisbach-D'Arcy formula may be used as follows:

$$H = \frac{a.l.v.v.}{d.2g} \quad \text{where:}$$

- H = pressure loss (in meters water column)
- a = peat slurry resistance coefficient
- l = length of pipeline (m)
- v = velocity of peat slurry (m/sec)
- d = diameter of pipeline (m)
- g = gravitational acceleration (g = 9.81 m/sec)

The peat slurry resistance coefficient "a" varies depending on:

- quality of peat (peat type, degree of decomposition)
- solids content
- velocity of the peat slurry
- pipeline diameter, and
- temperature of the peat slurry.

To develop a value for "a" for a peat deposit, a study of the viscosity of the peat slurry is required on samples taken from the peat bog using a laboratory viscometer. A number of viscosity determinations are required at different moisture contents which can be changed by adding water. Optimal solids content and maximum pumping distance may be calculated either by knowing the pumping characteristics of an actual mining peat slurry pump or by assuming that a pump can be constructed with the required capacity and discharge pressure characteristics. When the characteristics of the mining peat slurry pump (or the capacity with water which must be correlated to peat slurry) are known and the pipeline diameter, the peat type and degree of decomposition, moisture content and peat depths are also known, the optimal pumping distance and optimal solids content of the peat can be determined.

First of all, a representative peat sample from the deposit must be subjected to viscosity determinations at different % solids content (minimum 4 values) and viscometer rotational velocities. Viscosity versus viscometer rotational velocity at the different % solids levels can be plotted and pipeline velocity can be correlated to the viscometer rotational velocity. Knowing the mining peat slurry pump characteristics (capacity, pressure loss) and using the results from the plot of viscosity versus viscometer rotational velocity, then the coefficient of resistance for the pumping system may be determined, using the Weisbach-D'Arcy formula, (for the assumed pipeline length). The viscosities of the peat slurry for each coefficient of resistance may be calculated. It is possible to use the calculated viscosities with the viscosity versus solids contents information to obtain optimal solids concentration values for the assumed pipeline lengths. Optimal solids concentration is important to determine the amount of water to be added to prepare the peat slurry.

Knowing the seasonal capacity of the mining peat slurry pump (cubic meters of peat slurry for the season), the water addition requirement, design width of the pit, peat depth (less 20 cm bottom loss), and all mining losses (dikes, losses with stumps, freezing, peat slurry left in pit, etc.), the seasonal pit lengths may be calculated. Using the aforementioned information (about viscosity, solids content, velocity, etc.) and Figures 2-2 and 2-3, the optimal solids content can be determined for the various pipeline lengths.

When the pump characteristics for pumping peat slurry are not known, assumptions of peat slurry capacity and pressure loss requirements are based on previous experience. It is necessary then to design a mining peat slurry pump, or select an existing pump and use (or develop) the performance characteristics on water to determine the maximum capacity and distance at an optimal solids content when pumping peat slurry.

434 GENERAL CONSTRUCTION OF A MINING PEAT SLURRY PUMP

The mining peat slurry pump is a major equipment component for the large-scale equipment sets, because the pump performs the tasks of suction, grinding, maceration and pumping of the peat slurry to the process plant. A general description of a peat slurry pump has been included. Figure 4-7 shows a typical view of the mining peat slurry pump which is built with a lower suction part including an axial flow section, and on top, the elements of a centrifugal pump.

The peat slurry is sucked from the pit into the grinding and macerating section of the pump. This part of the pump 'processes' the peat slurry by cutting and grinding the peat to provide improved peat slurry characteristics for pumping. The construction of the centrifugal well (pumping section) provides for a maximum pumping distance of the peat slurry. To force back stumps, a propeller is used which repels stumps and breaks up lumps of moss peat. The main tasks of the propeller is to repel oversize material and also to provide a mixing action within the peat slurry in the pumping area to avoid settling of peat solids.

435 WATER SUPPLY AND TRANSPORT OF PEAT SLURRY

Figure 4-8 "Site Plan - Slurry Pump Dredge Mining System" shows four excavation areas (two sets of equipment per area). If the depth of the seasonal pits shown is about 4m or more, only one area will be required to produce the seasonal production of about 250,000 air-dried tonnes for an equipment set. To achieve the seasonal capacity, if the peat depth is less than 4m, then after excavation of one seasonal pit as shown the equipment moves directly to the second seasonal pit. The disconnected pipes from the pipelines are also moved to the second part of the seasonal pit and re-connected.

Figure 4-8 also shows the general layout of the water channels, working equipment sets, the peat slurry pipelines and the intermediate slurry reservoirs. For peat production, and to counter fire hazards, a water source is required, either from lakes, rivers, streams, etc.

Experience has shown that for every 1000 tonnes of air-dried peat (35% moisture content) produced by the Hydropeat method about 14,000 to 25,000 cubic meters of water is required, depending on stumps content and degree of decomposition. If a surface gradient exists on the peat deposit, water can flow by gravity through the distribution channels to the mining area. Length and diameter of all the water supply pipelines as well as channel sizes have to be calculated taking into account site-specific conditions.

The slurry from the mining area can be pumped directly to the process plant and depending on distance and whether additional equipment sets are in operation at other locations on the deposit, booster pumps and/or collecting reservoirs may also be required. Past practice with the Hydropeat method was to use a "transit reservoir" which commonly contained about 1500 to 3000 cubic meters surge capacity. A slurry reservoir containment berm was often constructed from mineral soil. A transit peat slurry pump recovered the slurry from the reservoir for further pumping to another transit reservoir or directly to the process plant by booster pump. This slurry pump was different from the pump on the mining equipment set and was similar to large capacity sewage handling pumps. Part 122 also discussed the construction of the slurry reservoirs.

436 CALCULATION OF PIPELINE CAPACITY AND TRANSIT PEAT SLURRY PUMP SELECTION

Pipeline capacity for the peat slurry pipelines is calculated considering the amount of production of all equipment sets pumping peat slurry. The pipeline capacity may be somewhat higher or less than the equipment sets and surges in production of the equipment sets can be compensated by the capacity of the slurry reservoirs. They should have a holding capacity of not less than 30 minutes of peat slurry flow from the producing machinery at the mining site. The net capacity of the pipeline is determined with a reserve of 10-12% which considers the utilization factors of the peat mining machinery and peat slurry pump at the reservoir.

Selection of a transit peat slurry pump (and calculation of pipeline diameter) is determined using the following equation:

$$H_1 + h < H \quad \text{Where:}$$

H_1 is the pressure loss in the peat slurry pipeline of length 'l' meters (in m of water column)

h is the elevation difference between the start and end of the pipeline (m).

H is the pressure loss in the pipeline at the operating capacity (m of water column).

When $H_1 + h$ is more than the maximum pump pressure, then alternative calculations may show an additional slurry reservoir, or a larger diameter pipeline or perhaps a larger capacity pump is required.

To calculate the diameter of the pipeline for pumping from a reservoir to the next reservoir or peat slurry storage area, the length of pipeline, the quantity in cubic meters of peat slurry and the characteristics of the transit peat slurry pump are considered. It is necessary to complete the design of the transit pumping and pipeline system and calculate the capital and operating costs of the system for certain pumps tested on peat slurry (and found to have suitable operating characteristics) in order to make the final selection of the transit slurry pump.

Table 4-2 shows the steps of a typical calculation to determine a suitable combination of pipeline diameter and transit peat slurry pump to meet the conditions shown. Table 4-2 shows the various factors considered for selection of a peat slurry pump for three standard pipe diameters, and illustrates how the factors can potentially be manipulated to achieve an optimal economic solution.

437 DIFFERENCES BETWEEN THE SLURRY PUMP DREDGE METHOD VERSUS THE HYDROPEAT METHOD

The Hydropeat method was described earlier in Part 1 as being a wet peat mining method used in the USSR for 40 to 50 years and finally discontinued in the early 60's for reasons outlined in Part 1. Although the method had a number of disadvantages which would tend to make it uneconomic to operate in North America, the operating principles were successful in producing a peat slurry of good quality for use as a fuel. In the preparation of this report, the authors have used some basic ideas from the Hydropeat system, but have made significant changes to develop new methods suitable for Canadian operating conditions. The main differences between the slurry pump dredge method and the Hydropeat method are as follows:

- a) With the slurry pump dredge method the peat slurry is pumped from the mining area directly to the processing plant, whereas with the Hydropeat method the peat slurry was pumped to drying fields. Using the slurry pump dredge method, the mining season is extended from 100 days (Hydropeat method) to 260 days. As a result the annual capacity in cubic meters of peat slurry is considerably greater.

The Hydropeat system required large areas for drying the peat slurry whereas the slurry pump dredge system requires none. For example, for one set of S.S. equipment, the drying area required for the peat slurry was about 500 ha. Bog preparation including clearing, ditching, etc. was required to prepare the drying areas.

Table 4-2 Selection of Suitable Combination of Pipeline Diameter and Peat Slurry Pump

Factors	Units	Standard Pipe Sizes		
		570mm	680mm	755mm
1. Quantity of peat slurry	cubic m/h	Q	Q	Q
2. Pipeline length	m	l	l	l
3. Peat slurry flow velocity	m/sec	V1	V2	V3
4. Viscosity of peat slurry	poise	n	n	n
5. Pressure loss for 100 m of pipeline	m (water column)	H1	H2	H3
6. Elevation difference	m	h	h	h
7. Total pressure loss	m (water column)	H1+h	H2+h	H3+h
8. Pump discharge pressure				
Model 1	m (water column)	Hmod1	Hmod1	Hmod1
Model 2	m (water column)	Hmod2	Hmod2	Hmod2
Model 3	m (water column)	Hmod3	Hmod3	Hmod3

As a rule, peat slurry drying areas were located at some distance from the peat deposit due to the large areas required, especially at high annual production rates. For example, 1 million tonnes per year of air-dried peat production required about 6000 ha of drying area using the Hydropeat method. Considerable lengths of pipeline and associated transit slurry reservoirs were required. For each tonne of final product produced by the Hydropeat method, 6.0-6.5 kg of steel was used for pipeline construction.

The Hydropeat system was labour intensive; a large number of workers were required especially for the drying operations. The drying operation also required forming, turning, harvesting and piling equipment.

- b) The slurry pump dredge equipment set is considerably different from the Hydropeat equipment. All slurry pump dredge equipment is mounted on a special (air-cushion) barge for ease of movement in the mining area. A peat slurry pump of new construction has been included which gives a good quality peat slurry. A crane with a long reach boom is mounted on the barge for clearing the mining area and removing stumps and roots from the working pit. The same crane is also used for dike construction and assisting in assembling the pipelines. The Hydropeat system used two separate cranes to carry out the above described functions. The slurry pump dredge has 4 hydromonitors and associated high pressure water pump stations mounted on the barge as compared to the Hydropeat method which used 4 manually-controlled hydromonitors placed on the deposit, away from the main slurry crane equipment set along with associated water pipelines. As well, the high pressure water pump station for the Hydropeat method was located separate to the main equipment set. The Hydropeat mining system used electric motors requiring overhead powerlines whereas the slurry pump dredge system will use diesel engines as a power source.
- c) The Hydropeat system often experienced slope failure, especially with peat depths greater than 4 m. Therefore, the slurry crane was supported by piles driven through the peat into the underlying mineral soil. The slurry pump dredge equipment is unaffected by working pit slope failures.
- d) The Hydropeat method required rail mounted on piles for movement of the slurry crane and high pressure water pump station. This is not required with the slurry pump dredge equipment.

438 HYDRO-SETTLING METHOD (MONENCO SYSTEM)

This method is also considered for large scale wet peat mining operations. The mining operation is the same as the slurry pump dredge system but transport of the peat slurry from the bog is directly to reservoirs near the process plant. The peat slurry settles in the reservoirs from a 3% slurry entering, to 9-15%. Water is removed by evaporation, seepage into the underlying ground, and possibly decantation. It is expected that the settling process may be accelerated by the use of chemical additives.

It has been reported that in Louisiana (Markman Peat Company), a dredge has been successfully used to pump peat to settling basins for thickening prior to further drying and preparation for horticultural use. Experience showed that the thickened peat, after removal from the settling basins, required a further drying cycle of about 8-10 days.

Figure 4-9 is a schematic which illustrates the arrangement of hydro-settling mining operation and slurry transport to the settling basins. As shown, the air-cushion barge equipment is the same as the slurry pump dredge method, however the slurry is transported directly to settling basins near the process plant. The slurry pump dredge system has limits to the scale of operation since all slurry is pumped directly to the process plant for use with only provision for slurry storage during the freezing season. The hydro-settling method uses large basins to store slurry for a longer period (possibly 1 year) for thickening, and as a result more readily handles fluctuations in production making the method more suitable to large scale operation.

The hydro-settling method may prove more flexible when used with solar drying compared to other dry mining methods used now, because:

- calculations show that the practical yield/ha using the Monenco method is expected to be higher as compared to conventional dry milling methods due to the ability to start drying operations earlier in the season,
- previous experience is available on the drying rates of various thicknesses of peat slurry using the wet mining methods,
- losses using conventional dry milling methods are expected to be higher than the Monenco hydro-settling method, considering the effect of rainfall, airborne particles and other production losses, and
- smaller drying area requirements for the Monenco method and the drying area is at the same location for the life of the operation, etc.

439 COMPARISON OF LARGE SCALE METHODS

.1 Slurry Pump Dredge System

ADVANTAGES

- a) This method can provide a suitable feedstock to the process plant with the following characteristics:
 - a peat slurry with a solids content 2.8 - 8.0% to give the highest practical yield for 1 cubic meter of raw peat,
 - the peat slurry is a homogeneous mixture of all layers of the peat deposit,
 - the special peat slurry pump provides grinding, macerating and mixing of the peat slurry,
- b) This method can be used on bogs with the following characteristics:
 - all bog types, all peatland types
 - minimum depth 1.5m (best suited to an average peat depth of 3-4 m for large scale operations),
 - ash content up to 23% (dry basis).
- c) A new design and construction of peat slurry pump is expected to give a higher capacity of peat slurry (about 1100 cubic meters/h of peat slurry) over a distance of about 2000m, of single stage pumping. The capacity of a single set of equipment is expected to be about 250,000 tonnes (air-dried, 50% moisture content) per season.
- d) The technology proposed for the slurry pump dredge system is based on many years of experience with the use of high pressure water jets on peat, the transport of peat slurry by pipeline and on knowledge of the effects of the various peat quality characteristics on the viscosity, slurry velocity and pressure losses in the pipeline system.
- e) This method has provision for the removal and handling of stumps.
- f) The method can be used on peat deposits up to 6m without undue risk of slope failure.

- g) The method can be used for a maximum number of days per year (about 260 days average) since all the peat slurry goes to the processing plant without solar drying.
- h) Although this method requires bog drainage, the mining area surface is not required to be cleaned of stumps and small trees on the surface since all the equipment is in the working pit. (This is as opposed to the Hydropeat system). No drying areas are required.
- i) Powerlines are not required since diesel engines are used.
- j) The transport of peat slurry by pipeline is based on many years experience; it is expected that the slurry pumping system can be automated.
- k) All the equipment in a set is together on a single barge allowing for ease of maintenance, supervision, etc.
- l) The equipment is available or easily fabricated in North America.
- m) Cost information can be obtained for further assessment of the method.
- n) After mining, the area can quickly be reclaimed for agriculture, silviculture, or other uses.
- o) Environmental impacts on adjacent areas are expected to be minimal.

DISADVANTAGES

- a) It is necessary to prepare the peatland i.e. a drainage system is required and large trees have to be removed. Mining operations can only commence after about 2 years when the near surface level moisture content is approximately 88%.
- b) Storage of peat slurry during the freezing season.
- c) It is necessary to have sufficient information on the peat characteristics of the deposit to calculate many of the mining and process factors.
- d) It is recommended that field demonstration testing be carried out on the various equipment components prior to actual production.

.2 Hydro-Settling (Monenco) Method

ADVANTAGES

This method has the same advantages as the slurry pump dredge system and several additional ones as follows:

- a) Exact matching of the mining equipment output to the process plant input is not as important due to the slurry surge capacity in the settling basins.
- b) The solids content of the peat slurry from the settling basins to the process plant will be higher than with the slurry pump dredge method.
- c) This method may also be used in conjunction with solar drying.
- d) It is expected that water may be recovered from the settling basin area for further use.

DISADVANTAGES

This method has the same disadvantages as the slurry pump dredge system and some additional ones including:

- a) A larger and more detailed experimental program is required to develop this method to determine the best settling basin technology including the use of chemical additives, and pumping tests on the settled peat slurry (about 15% solids) from the reservoirs to the process plant.
- b) Existing cost information on this method is not readily available and will have to be developed from further engineering evaluations.

4.4 SELECTION OF MINING METHODS FOR DRAINED PEATLAND

In section 3.4 it was explained that a ranking system was used to evaluate the most promising mining methods on undrained peatlands. The same ranking system has been used to evaluate medium and large scale methods on drained peatlands. In Table 4-3, results show that the slurry pump dredge is the preferred method since it meets more of the requirements of a feedstock to the process plant as outlined in Section 2.

4.5 RECOMMENDATIONS FOR FURTHER STUDY AND TESTING

The slurry pump dredge system requires field testing to prove the design for actual practice. The testing program required includes the following:

- a) Construction and then operation of the various equipment components under actual peat mining and pumping conditions (an important piece of equipment to construct and test will be the newly designed mining peat slurry pump).
- b) Assessment of the accuracy of the technical methodology including calculations about various factors such as solids content, viscosity, slurry velocity, pumping distance, pipeline diameter, etc.
- c) Determination of peat slurry losses during mining and transportation of the slurry.
- d) Determination of length of mining season, e.g. the onset of weather conditions which require suspension of mining activities.
- e) Determination of the abrasiveness, erosion and corrosive characteristics of the peat slurry on the pumping and piping system and best construction materials for each system.
- f) Verification of economic factors such as capital and operating costs of the method.
- g) Determination of the environmental impacts associated with the proposed mining method.

Results of the testing program can be expected to determine the likelihood of success of the proposed method for medium and large scale industrial applications.

Table 4-3 also indicates that the following two methods should also be considered as prospective alternatives, i.e. the Bucket Excavator (Bagger) and the Hydro-Settling (Monenco) systems. It is also recommended that further study be considered in the future on the Bucket Excavator (Bagger) and the Hydro-Settling (Monenco) methods if investigations of peat dewatering technology show them to be uneconomical, then either the Bagger and the Hydro-Settling (Monenco) system with solar-drying can be designed as alternative fuel peat producing methods.

Table 4-3 Results of Ranking for Wet Mining Methods
on Drained Peatland

D R A I N E D B O G					
		MEDIUM SCALE		LARGE SCALE	
Selection Criteria No.	Weight	Bucket Excavator (Bagger)	Bulk Peat Excavation	Slurry Pump Dredge System	Hydro-Settling Method (Monenco Method)
1	5	4	4	5	5
2	5	5	3	5	5
3	5	5	3	5	5
4	5	3	3	4	4
5	5	2	2	3	3
6	5	4	3	5	4
7	5	4	5	4	4
8	5	5	3	5	3
9	4	4	0	4	4
10	4	4	3	4	3
11	4	3	4	3	3
12	4	4	4	4	4
13	4	3	3	3	3
14	3	3	3	3	2
15	3	2	2	3	3
TOTAL:	66	55	45	60	55
%	100.0	0.83	0.68	0.91	0.83

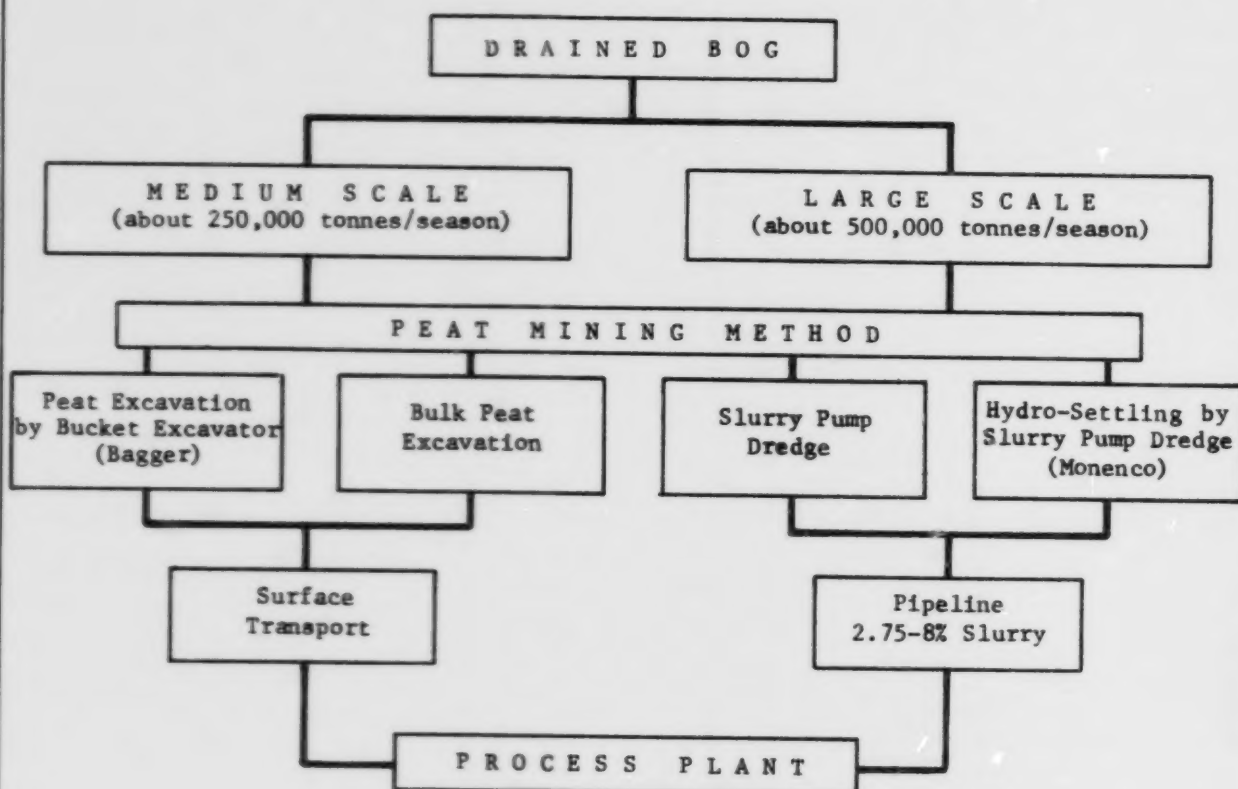
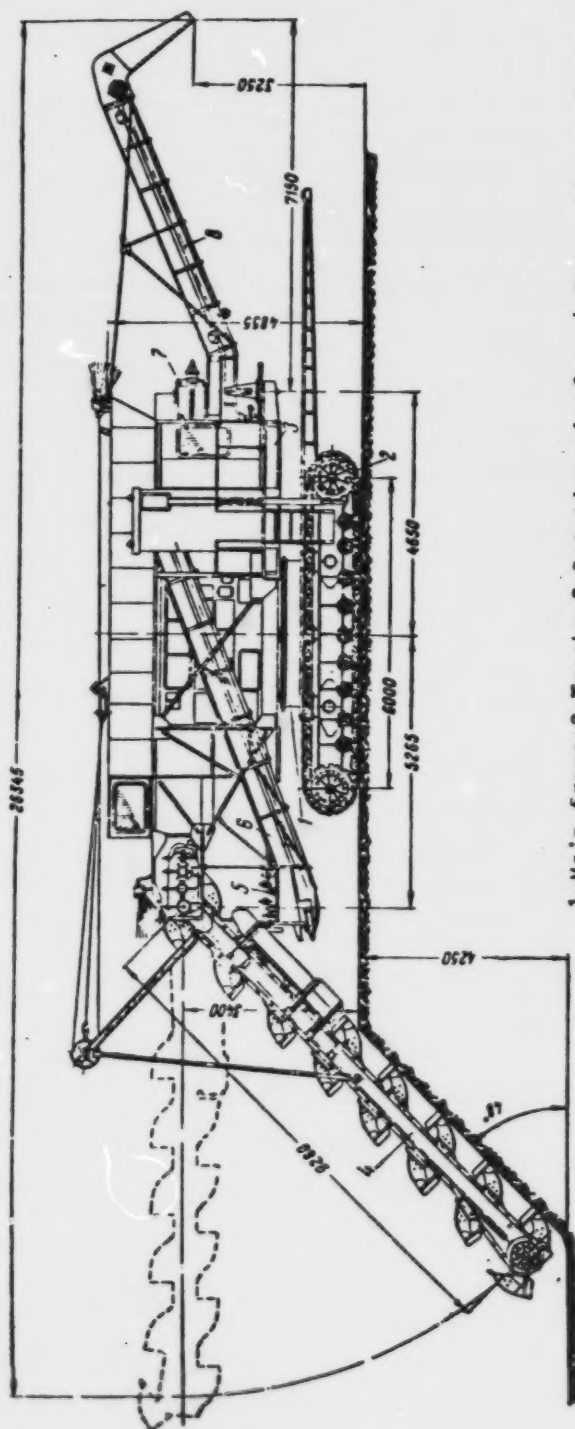


FIG. 4-1
 NATIONAL RESEARCH COUNCIL
 EVALUATION OF ALTERNATIVE
 WET PEAT MINING SYSTEMS
 PROPOSED WET PEAT MINING
 ALTERNATIVES FOR DRAINED BOGS



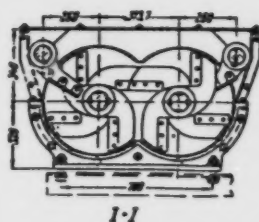
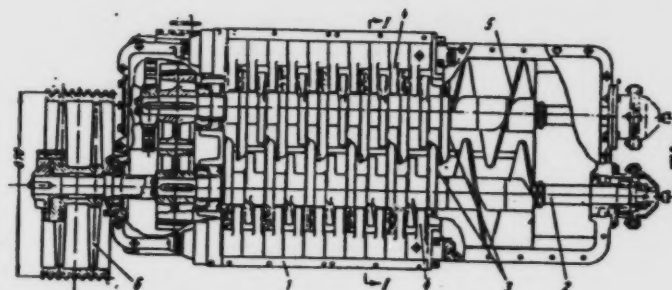
1-Main frame; 2-Tracks; 3-Rotating platform; 4-Excavating mechanism;
5-Separator; 6-Receiving conveyor; 7-Peat press; 8-Discharge conveyor;

FIG. 4-2

NATIONAL RESEARCH COUNCIL

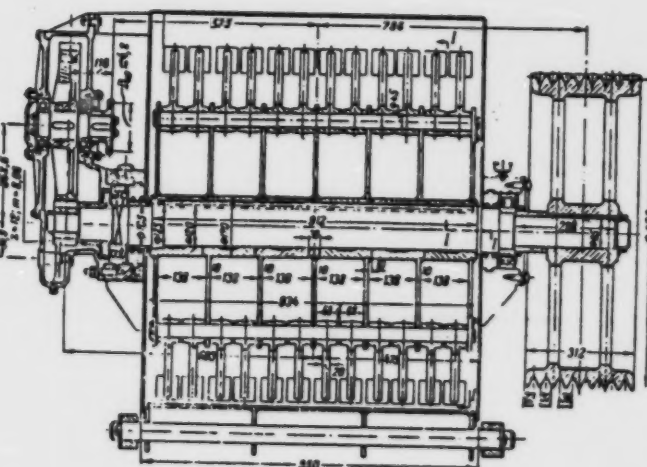
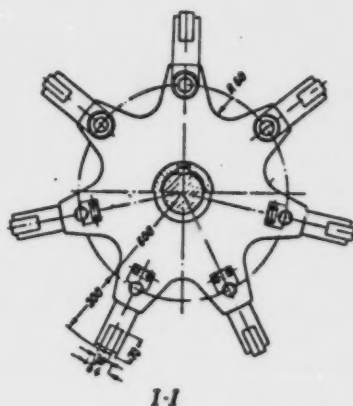
EVALUATION OF ALTERNATIVE
WET PEAT MINING SYSTEMS

**BAGGER EXCAVATOR
(USED WITH SPREADER MACHINE)**



- 1-Press housing;2-Press rollers;3-Rotating knives;
4-Static knives;5-Folding worm screws;6-Pulley;

PEAT PRESS



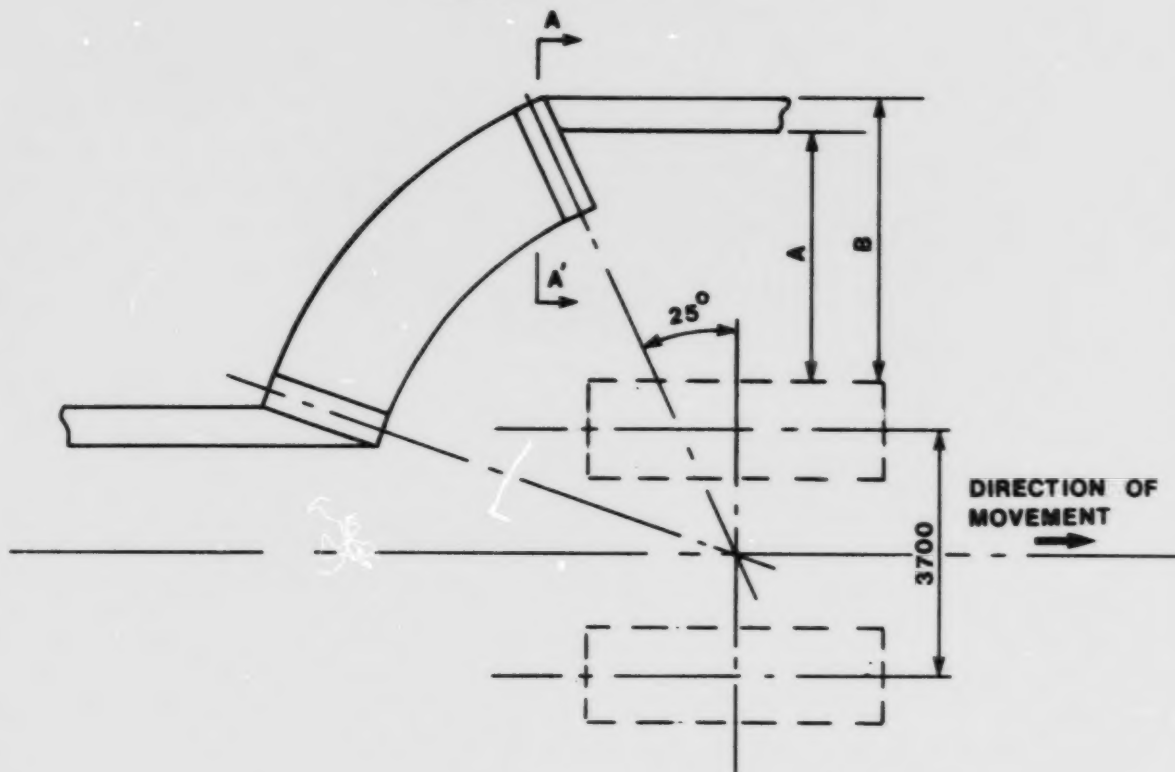
PEAT HAMMER MILL

FIG. 4-3

NATIONAL RESEARCH COUNCIL

EVALUATION OF ALTERNATIVE
WET PEAT MINING SYSTEMS

PEAT PRESS AND
PEAT HAMMER MILL
MOUNTED ON BAGGER EXCAVATOR



SECTION A-A'

FIG. 4-4
NATIONAL RESEARCH COUNCIL
EVALUATION OF ALTERNATIVE
WET PEAT MINING SYSTEMS
SCHEMATIC SHOWING
BAGGER MACHINE MOVEMENT

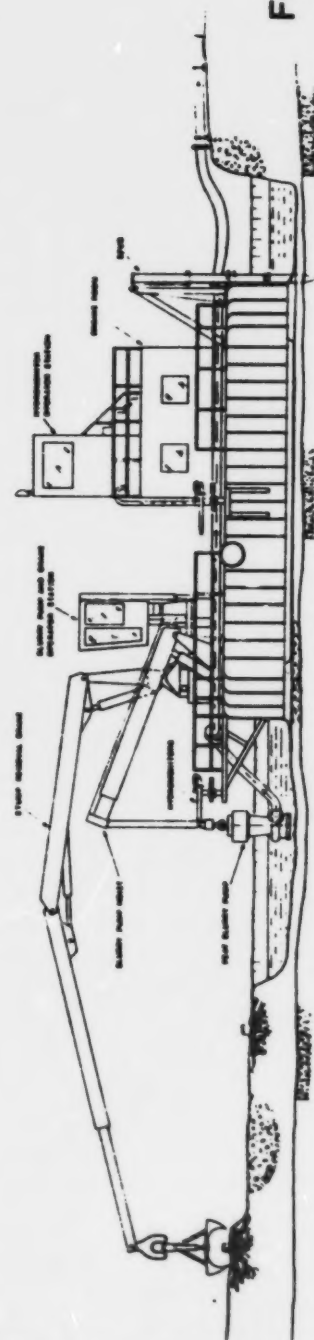
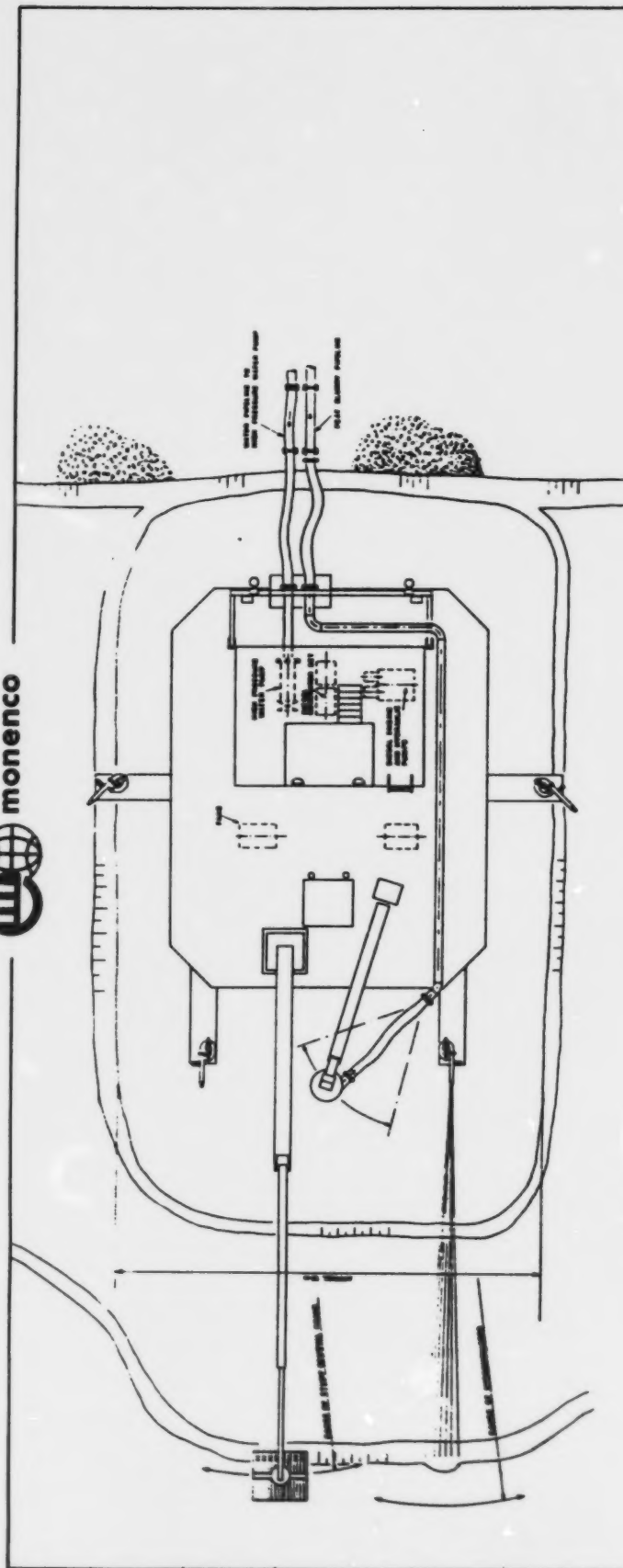
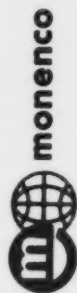


FIG. 4-5

NATIONAL RESEARCH COUNCIL

EVALUATION OF ALTERNATIVE
WET PEAT MINING SYSTEMS

GENERAL ARRANGEMENT
OF SLURRY PUMP
DREDGE EQUIPMENT

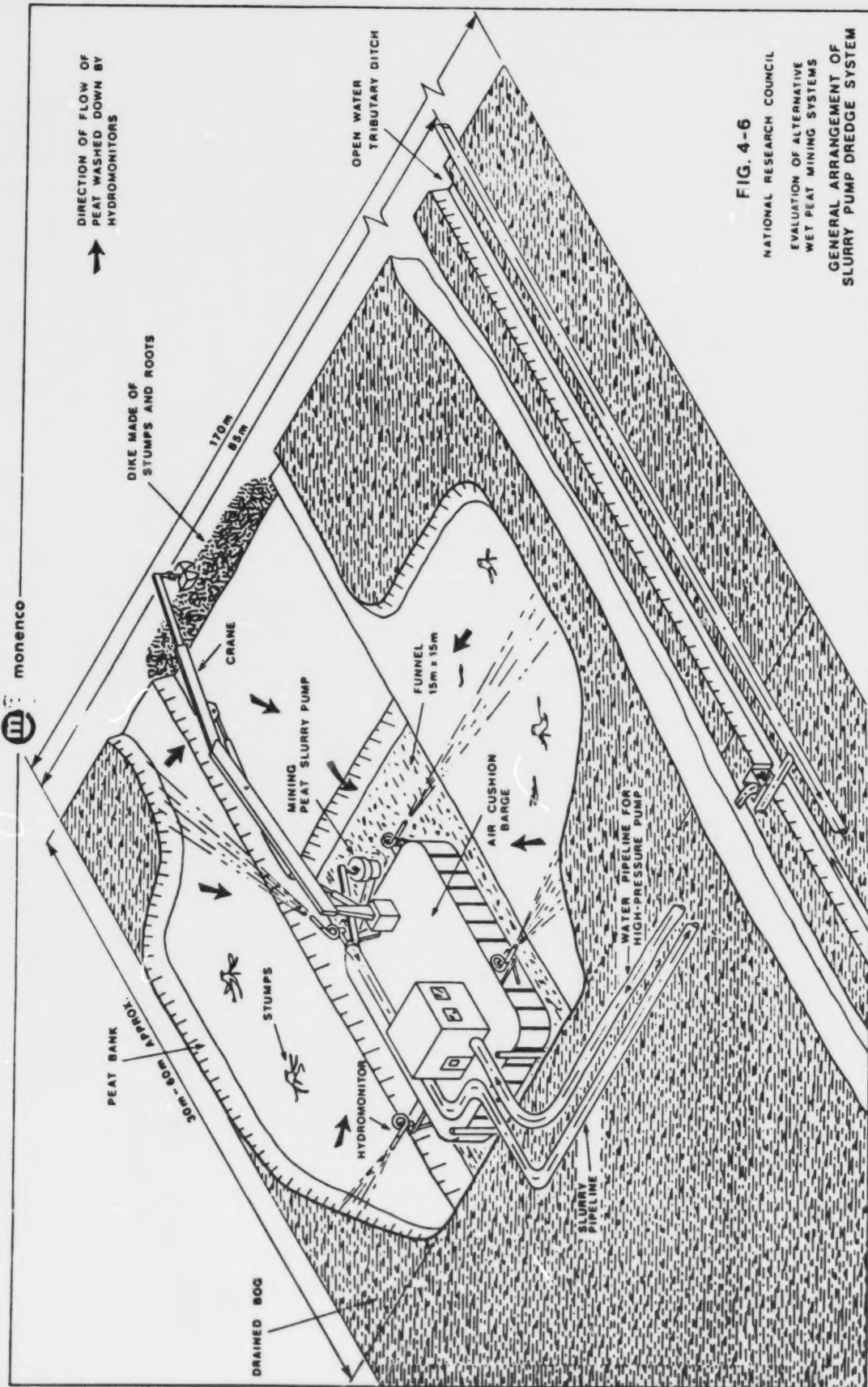


FIG. 4-6
NATIONAL RESEARCH COUNCIL
EVALUATION OF ALTERNATIVE
WET PEAT MINING SYSTEMS
GENERAL ARRANGEMENT OF
SLURRY PUMP DREDGE SYSTEM

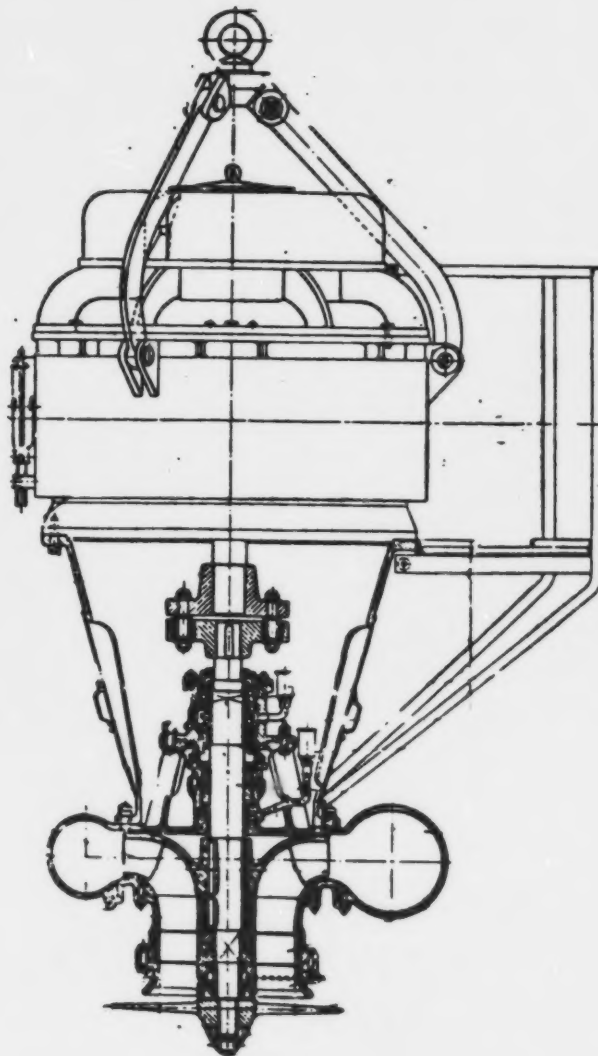


FIG. 4-7
NATIONAL RESEARCH COUNCIL
EVALUATION OF ALTERNATIVE
WET PEAT MINING SYSTEMS
MINING PEAT SLURRY PUMP

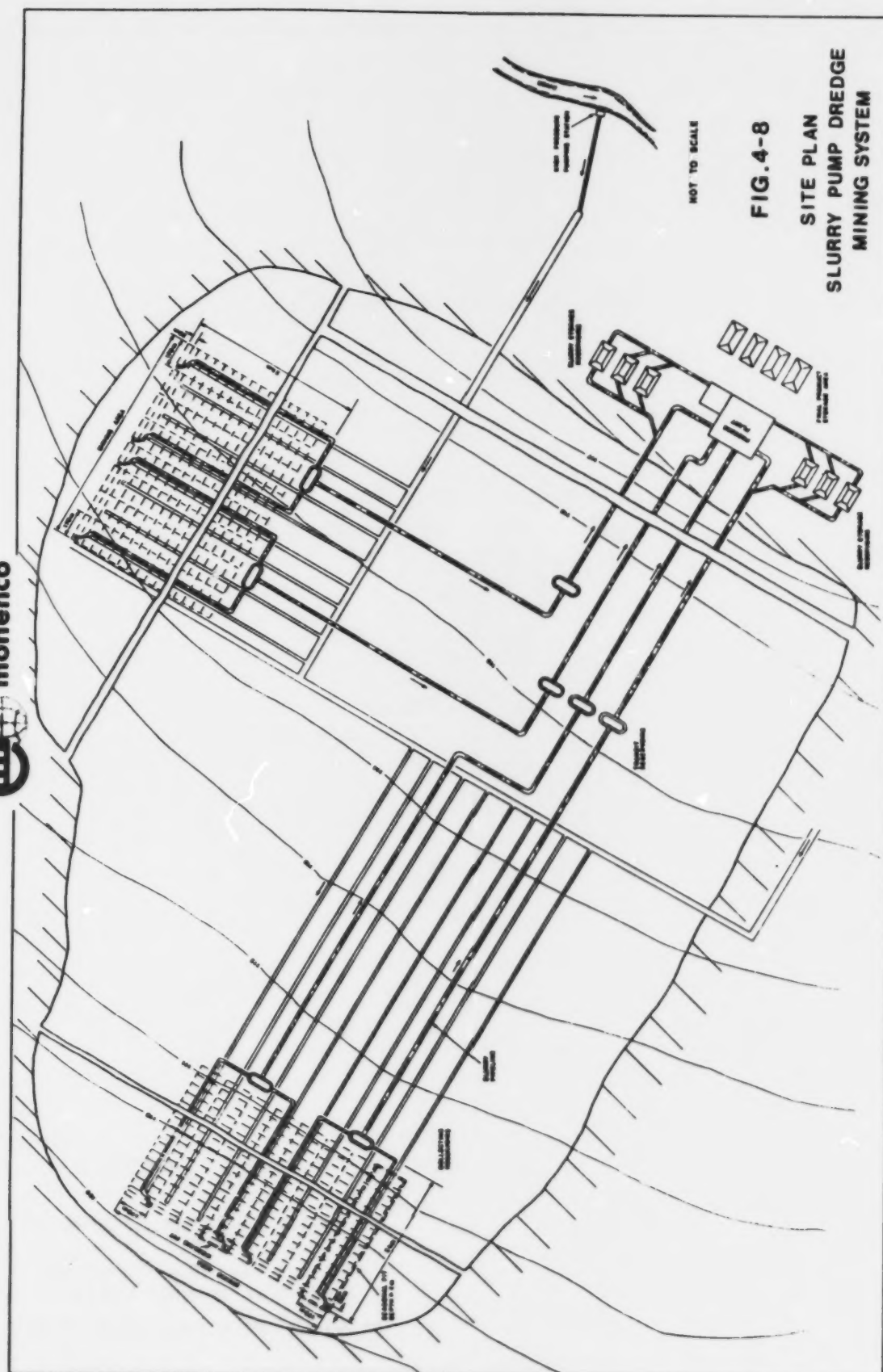


FIG.4-8
SITE PLAN
SLURRY PUMP DREDGE
MINING SYSTEM



FIG. 4-9

NATIONAL RESEARCH COUNCIL
EVALUATION OF ALTERNATIVE
WET PEAT MINING SYSTEMS
HYDRO-SETTLING BY
SLURRY PUMP DREDGE
(MONENCO METHOD)

PART 5

PEATLAND TRANSPORT

PART 5 - PEATLAND TRANSPORT

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5.0 PEATLAND TRANSPORT

5.1 PEATLAND TRAFFICABILITY

511 INTRODUCTION

It has long been recognized that undrained peatland is a major mobility obstacle to off-road vehicles. Since 1946, a considerable amount of research has been conducted in Canada to attempt to identify and quantify the relationships between peatland and vehicle mobility. These efforts are still continuing, but it is clear that although some vehicle designs are better than others, vehicle mobility always deteriorates with increasing vehicle weight and number of passes of the vehicle over the same piece of peatland. This conclusion is supported by the results of several mobility and trafficability research projects, much of which has been published. A brief review of the relevant aspects of this experience follows. Mr. J.R. Radforth, P.Eng., of Peat Consultants Canada Ltd., assisted in the preparation of this part of the report.

512 PREVIOUS RESEARCH AND TRAFFICABILITY TEST PROGRAMS

From 1946 to 1961, much of the muskeg trafficability research in Canada was directed by Dr. N.W. Radforth at McMaster University in Hamilton. The main results were identification and classification of peatland features, airphoto interpretation of these features and establishment of qualitative relationships between the features and trafficability (Ashdown and Radforth, 1966).

This was followed in the sixties by an intensive search for off-road vehicle concepts which would provide the highest possible mobility over peatland. There was much field testing of tracked, wheeled, and air-cushion assisted vehicles on many peatland conditions. An analysis was made of the factors contributing to vehicle immobilization. A paper by Schreiner (1967) reported the results of multipass tests with tracked vehicles and related cone penetrometer measurements to number of passes successfully completed by tracked vehicles of various weights. Vehicle weight and track perimeter (not area) were identified as the critical vehicle parameters in predicting mobility on a go/no go basis. Further tests attempted to quantify vehicle performance such as drawbar pull, slip, sinkage, power, etc., and link the values to terrain characteristics, including multi-pass trafficability. Both the test results and field experience clearly demonstrated the strong effect of vehicle weight and moisture content of the terrain on vehicle mobility. In no case did undrained peatland used in the tests (carried out near Parry Sound, Ont.) support more

than 100 passes of a vehicle and often only twenty or thirty passes were successfully completed before the vehicle became immobilized.

One test series included a tracked vehicle fitted with a Martin track, which has a modular rubber construction and good pressure distribution as compared with belt tracks with steel grousers. Multiple-pass tests showed that the Martin Track could make up to twice as many passes without being immobilized as could a conventional track. These results demonstrated the importance of maintaining the integrity of the surface mat of the peatland if the original trafficability is to be preserved.

Tests with an articulated logging skidder fitted with various sizes of tires revealed the practical value of the largest possible tire diameter and width for the best mobility on peatland. The effects of changing tire inflation pressure and tread pattern were noticeable but less dramatic. A more recent test on shallow forested peatland, conducted by Forest Engineering Research Institute of Canada, has emphasized these results.

In the early seventies, public concern developed regarding environmental disturbance arising from petroleum exploration and development activities in the western Arctic and in the Arctic Islands, where much of the terrain is tundra with a shallow peat layer and permafrost. Multi-pass tests with both tracked and wheeled vehicles were carried out on a variety of tundra test sites (Radforth, 1973). The results showed the effect of the number of passes, vehicle weight, and tread aggressiveness on the level of disturbance of the vegetation cover. As well as these factors, slope, water content and season also emerged as important parameters affecting disturbance level. These tests were augmented by observation of the long-term effects of vehicle traffic during the vehicle tests of the mid-forties near Churchill, Manitoba (Radforth, Korpijaakko, Radforth, 1972).

Two additional programs in the western Arctic (13,17) examined the factors affecting establishment and use of winter roads. Much of this work was rationalized in an off-road transport planning scheme which takes into account the transport mission, equipment capability, and environmental implications.

A paper prepared in 1976 (Radforth, 1976) describes experience with tracked vehicles operating on corduroy roads over forested peatland. Although this project established the practicality of using tracked vehicles on corduroy roads for specialized, limited traffic over peatland, it also showed that tracked trailers and even wheeled vehicles would be unsuitable. It was also found that the corduroy road had a limited lifetime which was determined by the vehicle weight and number of passes. Part of this problem might be alleviated by using Martin tracks, as mentioned earlier.

In 1978 a study was conducted of the factors limiting travel speeds of off-road logging vehicles. This included an extensive literature review and an analysis of the effects of soft ground on vehicle mobility. This analysis has been taken into account in considering system alternatives for transport of peat from the excavation site to a process plant in the present study of wet peat mining systems as well as more recent experience in peatland studies and projects.

Work by Dr. J.Y. Wong of Carleton University, J.R. Radforth, et al, involved the use of a portable Bevameter with a computerized system for on-the-spot output of terrain values in load-sinkage and load-shear tests. The results were correlated to von Post and Radforth classifications of the test sites, and showed to some extent the dependence of the mechanical properties of the terrain on cover type and moisture content. A mathematical model for predicting peatland response to vehicle weight and tractive loading was proposed, and took into account the tensile strength of the surface vegetation mat.

513 TRAFFICABILITY CONSIDERATIONS FOR WET PEAT MINING SYSTEMS

Research and experience has indicated that tracked or wheeled vehicles travelling on an unprepared, undrained peatland surface would not be suitable for transport of mined peat to a process plant. The weight of the loaded vehicles and the high number of passes required would greatly exceed the bearing strength and durability of the peatland surface. Even advanced vehicle concepts like Terra-tires (wide, low inflation pressure) and the Martin Track would not have sufficient mobility for this purpose. Off-road vehicle traffic can only be supported by peatland if it is well drained (even then only in dry weather or during the winter) or if it is protected by a roadway of some kind.

5.2 EVALUATION OF TRANSPORT SYSTEMS FROM THE BOG TO THE PROCESS PLANT

521 POTENTIAL SURFACE TRANSPORT METHODS

In this study, surface transport is being considered only for drained bogs. Several methods of transporting the peat have been considered, and include:

- Earthmovers and scrapers,
- Railway/monorail/elevated railway,
- Tracked vehicles,

- Wheeled vehicles,
- Conveyor (belt),
- Overhead cable,
- Tractor and sleds,
- Winch and sleds,
- Corduroy road and tracked or wheeled vehicles,
- Ice roads and trucks, and
- Barges.

These methods have all been used in the past for transporting peat and/or equipment over peatland. For wet mining, only some of the candidates are likely to be technically acceptable because of the constraints identified in the following section.

522 FACTORS AFFECTING THE SELECTION OF TRANSPORT METHODS

The factors affecting transport selection include:

- system output required (capacity) - at medium scale, about 250,000 tonnes/year of air-dried peat at 50% moisture content;
- moisture content of the raw peat (in situ);
- moisture content of transported peat;
- effect of weather, e.g. heavy rainfall;
- distance to process plant;
- location of plant - on or off the bog;
- transport speed;
- type of terrain surrounding the peat deposit;
- surface preparation of peatland along transport path;
- existing roads, railways, waterways;
- length of transport season and operating season;

- ease of re-locating the transport system as the excavation site moves;
- local transport for pre-processing the peat at the excavation site;
- method of loading the peat at the excavation site;
- handling of the peat at intermediate points along the transport route (e.g. transfer from barge to truck);
- unloading the peat at the process plant, compatibility with storage facility;
- manpower requirement; need for special skills and training to operate;
- equipment availability - conventional machinery or custom design and build;
- variety of equipment used, including maintenance skills, spare parts inventory and need for service facilities;

523 IMPORTANCE OF FACTORS

Several of the factors require elaboration, as they are critical. Others vary in importance depending on actual circumstances. This implies that there is no single optimum design for a surface transport system, and that each situation must be examined on its own merits. However, some general limitations do emerge when the possible systems are evaluated in terms of the above factors.

It is assumed that the annual quantity of peat to be delivered to the process plant is about, or equivalent to, 250,000 tonnes at 50% moisture content (medium scale). If the moisture content of the raw peat loaded into the transport system ("raw" peat) ranges from 70% to 90%, then the transport system must be capable of moving 417,000 to 1,250,000 tonnes of raw peat per year (excluding losses). The example demonstrates that the required capacity of the transport system is dependent on the moisture content of the peat to be transported, which in turn depends on the extent to which the peat deposit has been drained.

.1 Moisture Content of Peatland

At 90-95% moisture content in the surface layer of peat (undrained peatland), mining will result in open water in the excavation, with the water level within a few centimeters of the ground surface. Although low-ground-pressure tracked and wheeled vehicles can travel a few passes over the same path in these conditions, further repeated traffic results in the equipment becoming immobilized as the shear strength of the terrain surface deteriorates. Any surface transport system for these wet conditions must be designed to preserve the surface integrity of the peatland, or, alternatively, float in the open water of the excavation.

When the water table in the peatland is lowered to about 1/2 to 1 m below the surface, and the moisture content of the peat is considerably reduced at the very surface by drainage and evaporation, the peatland will often support repeated traffic by wheeled vehicles. Between the two extremes of moisture content, the terrain will support some light traffic by heavy off-road transport vehicles. There must be some means, such as a prepared road bed (e.g. railway) of protecting the peatland surface from localized, repeated weight and traction loading.

.2 Effects of Weather

Day-to-day changes in airborne moisture, temperature, sunshine, wind velocity and direction significantly affect the surface condition (moisture) of drained peatlands and their ability to support traffic loads. Reliability, and therefore output, of the transport system, if it depends on the surface shear strength of the peatland, is affected on a day-to-day basis by the weather. For example, the day after a heavy rainfall, a shallow depression in the peatland surface can immobilize a vehicle which had previously passed through it without difficulty. Therefore, if the transport system must be able to operate every day regardless of the weather (during the operating season), it should be designed to be unaffected by local changes in the shear strength of the terrain surface due to weather.

.3 Distance to Process Plant, Plant Location, and Transport Speed

These factors affect not only the capital cost of the surface transport system but also the selection of equipment. For example, in a truck or barge system, the number of trucks or barges, their capacity, travel speed and travel distance must be taken into account so that they match the excavator output and the demand at the process plant. If the travel speed is slow, or the distance is great, the result is a long cycle time and more transport units are required to act as travelling storage between the excavator and the plant. The plant location, on or off the peat deposit, will determine whether intermediate transfer and handling points (e.g. change from barge to trucks) will be required.

.4 Terrain

The type of terrain surrounding the peat deposit will affect road construction techniques. For example, in the Pre-Cambrian Shield, road construction can require blasting and moving rock. This affects the costs considerably of the transport system between the excavating site and the process plant.

.5 Surface Preparation of the Peatland

As mentioned earlier, undrained or poorly drained peatland requires either a means of protecting the ground surface from traffic damage or a transport system which operates in the open water of the excavation. In the former category are included plank roads, corduroy roads, railways, road embankments on geotextiles, or ice roads in the winter. Any attempt to travel over the undrained or poorly drained peat deposit more than a few passes with wheeled or tracked vehicles will fail because of immobilization of the vehicles. Wet peatland will support varying amounts of vehicle traffic, depending on vegetation cover, moisture content of the peat, vehicle weight, ground pressure and aggressiveness of tracks or tires. While light vehicles may travel over 100 passes in the same path before being immobilized, heavy vehicles (more than 10 tonnes, ground pressure over 0.21 kg/sq.cm) do not usually exceed 40 or 50 passes. For a peat transport system, hundreds of passes over the same path would be required. This rules out the use of such vehicles for peat transport over the unprotected peatland surface unless the peatland has been well drained for several years.

A plank road is successful on undrained peatland surfaces which are almost uniformly flat. When used on rough peatland surfaces, a plank road requires extra support from logs or timbers in the depressions in the ground surface. The supports strengthen the roadway and level its surface, enabling vehicles to travel faster. This type of road provides a smooth running surface for light, rubber-tired vehicles and by using heavier reinforced planks and ties, it is conceivable such roads might be suitable for heavy trucks.

Materials for plank roads are readily available and relatively inexpensive. The roads are easy to maintain and relocate and with light vehicles, it is expected speeds of 10-15 km/h could be achieved. For two-way traffic, turn-outs and turning areas would be required, as well as a traffic control system when several vehicles are involved. Alternatively, the road could be built in loops, with one-way traffic on each loop. The roadway should be designed to prevent derailment of vehicles.

The need for traffic controls, turn-outs and turning areas also applies to other types of prepared roadways. Furthermore, corduroy roads, if not covered with fabric and soil/peat/gravel, require the use of tracked vehicles. Wheels can easily force logs in the corduroy apart and drop between them, disturbing the road and immobilizing the vehicle. Also use of corduroy implies an abundant and readily available supply of logs or timbers, both for building the road and for replacing worn and broken logs later.

Railways on raised (dried) peat embankments are used successfully in Ireland for peat transport, but there the peatland is always drained. Use of this method on undrained or poorly drained peatland might be successful in some cases, especially if the roadbed incorporates geotextiles to confine the movement of the peat in the roadbed. There is the danger, however, that the locomotives and loaded carriages, even though considerably smaller and lighter than conventional rolling stock, would overload an undrained peatland surface with its low bearing strength. Full-scale tests would be necessary to determine whether a particular peatland could support this type of loading successfully.

Road embankments using geotextiles and granular fill have been successfully established on peatland (undrained) in the past. This approach would be particularly suitable for perimeter and other permanent roads which do not need to be relocated as mining of the peat deposit proceeds, but should be avoided on the peat deposit because of contamination of the peat by the granular fill.

Ice and snow roads could be built during the winter in most parts of Canada where peat deposits are plentiful. Although the length of time which these roads can be used each winter would not be precisely predictable, ice roads will support traffic by all kinds of heavy vehicles, even over open ponds. The roads can be located at will and simply disappear in the spring thaw so that their presence does not interfere with future peat excavation.

.6 Length of Transport Season

Wet weather in the autumn and spring, and snow and cold temperatures in the winter have a significant impact on the availability of transport systems and vehicles. Haul roads deteriorate rapidly in wet weather and require more maintenance and reduced traffic loads. Snow removal in winter is a costly activity, and this cost cannot be ignored in evaluating the economics of a proposed transport system. Ponds and canals freeze, as do the outer layers of wet peat stockpiles. An all-weather roadway requires more attention to drainage and fill quality than dry-weather roads, making them more costly.

On the other hand, if the peat transport system is required only on a seasonal basis, its capacity must be increased to enable it to meet the yearly output required. The cost of the extra capacity must be weighed against that of operating year-round.

.7 Movement of the Excavation Site

As the excavation site moves around on the peat deposit, the surface transport system must be continually adjusted to adapt to successive new locations. One possibility is to excavate narrow strips adjacent to the transport route. Then, if the route is located so that the cutting face is the maximum possible length, relocating the route will only be necessary occasionally, whenever a new cutting face is started. Obviously, the depth of the peat deposit also affects the frequency of relocation.

.8 Activities at the Excavation Site

It is difficult to separate discussion of the surface transport system from that of the excavation method. At the excavation site, the peat may require some processing, such as wood removal or temporary stockpiling to allow excess water to run off. Alternatively, the excavator may remove the peat from the deposit and place it immediately in the transporting vehicle.

Again, because of the low bearing strength of undrained or poorly drained peatland, it is unlikely that there can be much local surface traffic at the excavation site. Processing equipment could probably use short conveyor systems effectively and would be best located on the excavator or accessory equipment, e.g. Bagger excavator.

.9 Intermediate Transfer

Some transport systems, such as barges, may not be able to travel the entire distance between the excavation site and the process plant, and the peat will have to be transferred to another form of transport at some intermediate point. Unless there is a plan to have a stockpile at the process plant, and if the stockpile can be located at the intermediate transfer point, then this transfer operation will require extra equipment, space, support and operating time. Therefore the cost of providing the required transport capacity is increased. If possible, the transport system should be able to move peat directly from the excavating site to the process plant without interruption.

.10 Equipment Design and Selection Factors

The remaining factors affecting selection of the transport method are related to equipment design. Even if a system is mechanically capable

of moving peat to the process plant, the complexity of the unloading operation at the plant is important (e.g. dump trucks versus rail cars, the manpower required to operate the system, as well as to install and maintain it, any special skills needed and can they be obtained locally, equipment complexity and availability and ease of repairs and maintenance). These and similar questions must be asked when selecting an optimum surface transport system for peat.

524 SELECTION OF SURFACE TRANSPORT SYSTEMS

It is probably impossible to select a single optimum surface transport method which can be applied generally, because controlling factors will vary from site to site. However, it is possible to isolate the controlling factors which affect the selection of the possible systems and that one or two candidates will emerge as preferable.

First, the system capacity should be determined. The pertinent factors are annual capacity, seasonal operation and moisture content of the peat to be transported. Next, a description of each system considered is prepared, keeping in mind the constraints described earlier. For example, if the raw peat moisture content for transport is 83.3%, then 750,000 tonnes per year of wet peat must be delivered to the process plant to produce 250,000 tonnes per year at 50% moisture content (assuming 100% efficiency). If the operating season is between the first of June and the end of September, with a 12 hours a day operation, six days a week with 90% availability, then the system capacity works out to about 680 tonnes per hour. If trucks of 15 cubic meters capacity each are used, and determining a cycle time for, say a 2 km haul, then a certain number of trucks are calculated to be required (about 16).

This type of analysis is only the starting point for evaluating each transport system candidate. Before it is assumed that this or any other system is viable, the impact of the constraints on the viability of the various transport systems must be examined.

.1 Annual Capacity, Seasonal Operation, Peat Moisture Content

The amount of raw peat to be transported to supply the process plant requirement (e.g. 250,000 tonnes per year at 50% moisture content for medium scale operation) depends on its moisture content. If the peat deposit has been drained and the peat prepared so that the moisture content is 80%, then 625,000 tonnes per year of raw peat will have to be transported (excluding losses). If the initial moisture content was 95%, the figure would be 2,500,000 tonnes per year (excluding losses). The figures show the impact of moisture content on required system capacity.

If it is assumed that an undrained peat deposit has an average depth of 2.25 m, and the life of the deposit is 25 years, then the required surface area of a single deposit would be about 28 sq. km. If the width were 2 km and the process plant were located on the edge of the deposit at the mid-point, then transport distance from the excavation site to the plant could be as much as 9 km.

From a practical point of view, winter excavation and transport is expected to be more time-consuming, difficult and costly than working in the summer, especially if a summer operation must be adapted to winter conditions. Low temperatures and snow are the obvious basic problems. Barge canals and excavation sites freeze up. Peat will freeze in transport vehicles making unloading difficult. Snow can mix with the peat, increasing the moisture content (reducing the system capacity). Frozen chunks of peat can plug or damage process or transport machinery, and field maintenance of equipment becomes more difficult and costly than during warm weather.

On the other hand, snow and ice roads are easy and cheap to construct (given low enough temperatures and sufficient snow) and can support conventional trucks, loaders and excavators. For this type of transport equipment, there is an opportunity to extend its use into the winter, reducing the capital cost of system capacity.

For Canadian conditions, it is estimated that summer-type operations can be conducted from late May/early June to possibly early November and that winter transport on snow/ice roads can extend from the beginning of January to mid-March. During fall freeze-up and spring thaw, freezing conditions and snowfall can interfere with summer-type operations but conditions are also unsuitable for winter operations. Therefore, it is estimated that summer systems can work for about 24 weeks per year and winter systems for about 11 weeks per year.

525 EVALUATION OF ALTERNATIVE TRANSPORT SYSTEMS

In this section, system candidates are evaluated in the light of the constraints. It appears that to be successful, a peat transport system will have to operate on the peatland surface, work either during the summer or both summer and winter, work over distances up to 10 km, and be suitable for relocation as the excavation site moves. On the basis of these criteria alone, several systems appear unsuitable.

.1 Barges

Barges work only in the summer in a flooded excavation. Since only drained peatland is being considered for surface transport systems, it is unlikely that there will be enough water in the excavation to float barges large enough to provide the required capacity. (Drained peatland in this context means poorly drained, lowering the water table by only a few centimeters.)

.2 Corduroy Road

Construction of up to 10 km of corduroy road would require handling a large number of logs. If each log averaged 25 cm in diameter and two logs come from one tree, then 10 km of road would require 20,000 trees, a major logging project. Either the trees would have to be conveniently located near the peat deposit or there would have to be a requirement to clear heavily wooded peatland for the mining operations to obtain an adequate log supply. A corduroy surface with no cover is rough, reducing travel speeds to under 10 km/h, and can only be used effectively by tracked vehicles.

.3 Winch and Sled

The difficulty of laying, handling and relocating heavy wire rope over distances up to 10 km is a questionable idea. For operation to and from the excavation site, either a second cable for back-haul or a sled-mounted winch would be required. For a single sled travelling at 5 km/h over a distance of 10 km, a round trip would take four hours. If one hour is allowed to load and one hour to unload, the cycle time is 6 hours and the sled would require a capacity of 6 hours x 680 tonnes/hour = 4080 tonnes. Even neglecting the weight of the sled and assuming winch line pull is 75% of the weight, then the line pull would be as high as $0.75 \times 4086 = 3065$ tonnes. The largest wire rope listed in Machinery's Handbook is 3.5 inches in diameter, has a breaking strength of 408 tonnes (449 tons) and weighs 28.3 kg/m (19 lb/ft). Considering a minimum recommended safety factor of 5, the amount of cable used and the power requirements to operate the system make it impractical. For example, 16 trucks at 200 HP apiece represent only approximately 6% of the power requirement for the winch and sled arrangement to do the same useful work.

.4 Belt Conveyors

Belt conveyors are generally most practical over short and even medium distances up to one or two kilometers. Large belt conveyor installations are used in the tar sands operations in Alberta. Such large capacity installations require a stable foundation not found on poorly drained peatland and generally are very cumbersome to relocate as the excavation proceeds. Small conveyors can be moved quickly with light cranes for short distances as excavation gradually moves. For these reasons, conveyors are most useful as feeders and loaders around the excavation site and at transfer points.

Severe icing problems can be expected with conveyors if they are used for moving wet peat during the winter.

.5 Tracked and Wheeled Off-Road Vehicles

Tracked and wheeled vehicles operating on the peatland surface seem to provide the most flexible transport system, as they can follow the excavation site easily. However, there are severe limitations to the trafficability of the peatland surface which restrict the amount of traffic from such vehicles. The equipment can be used for repeated passes over the same ground only if the peatland has been drained well for several years and then only on frozen winter ground or during dry periods in the summer. During heavy rains or spring thaw when the ground surface is temporarily wet, immobilization can easily result, especially for heavy vehicles carrying 15 tonnes or more. Therefore this type of transport system is really only suitable for "dry" mining systems, and not for "wet" mining methods as considered in this study.

.6 Earthmovers and Scrapers

Use of earthmovers and scrapers would require intensive previous drainage and shallow peat (probably less than 1 m) underlain by well-drained sandy soils to provide adequate trafficability for this type of equipment. While these circumstances may occur in special cases (e.g. over the tar sands in northern Alberta) they are not generally the case in other parts of the country. Another potential problem with this method is that it would mix mineral sub-soils with the peat. Therefore, except for the special conditions mentioned, this approach does not appear to offer a realistic, dependable alternative for transporting peat to a process plant.

.7 Overhead Cable

Overhead cables transporting heavy loads need supporting pylons or towers with reliable foundations. Because of the traffic on the cable, the foundation loads would be dynamic as well as static (in addition to wind loads). When this problem is added to ice loading, the generally poor bearing support for foundations in many places beneath the peat deposit, the need to relocate the transport route from time to time and the need for ground-level access with heavy equipment to install the pylons and cable, the use of an overhead cable system for transporting peat over long distances appears impractical.

.8 Roads and Railways

Other systems considered include a railway/monorail/plank road and ice roads with trucks. Railways (narrow gauge, light equipment) have been successfully used for peat transport in Ireland for many years. A

monorail system is currently in use in northern Scotland, and a plank roadway has been used experimentally on a small project in Ontario. The monorail and plank road have not been used however, to transport hundreds of thousands of tonnes of wet peat, so their practical advantages and limitations have not yet been fully explored.

Based on the Irish experience, a railway system can be built on a raised peat embankment and could be expected to perform reliably in Canada for a major part of the year. Heavy snowfall would necessitate use of snow removal equipment, and ice accumulations could be expected to be a problem during freeze-up or spring thaw. Relocation of parts of the railway from time to time would be a labour-intensive item, which would tend to be costly. To reduce weight and traction loads to a minimum, small, light-weight rolling stock would be necessary and this may be difficult to obtain readily.

The versatility of conventional construction equipment (trucks, loaders, etc.) is an extremely attractive feature. Medium dump trucks can carry about 15 cubic meters or about 16.5 tonnes and travel at highway speeds on good roads. Regardless of what peat transport system is used, surface access to various parts of the peat deposit with light personnel and service vehicles will be required in any case, so that some roads will be needed.

Granular fill on a geotextile membrane would be acceptable at least around the perimeter of the peat deposit, but likely could not be used over the deposit as the granular fill could easily mix with the peat, spoiling it for use later. This problem would arise especially during relocation of a granular fill roadbed.

A plank road for trucks appears to be an attractive concept, even though it is essentially untried at this time. A heavy plank road can be constructed at relatively low cost. As pointed out earlier, only 16 trucks working in the summer would be needed to transport the required amount of peat, and trucks are readily available. Trucks can also operate on ice roads in the winter, and are compatible with many other types of construction machinery such as loaders and excavators.

The main drawback of a plank road system is that it has not been used before for heavy trucks, so its performance is not precisely predictable. Conceptually, however, the method offers reliable, high-speed transport at minimum initial and maintenance cost, and could be designed for rapid relocation with light equipment and low labour requirement. By using trucks, the system would be compatible with existing road systems, eliminating the need for transfer points between the excavating site and the process plant.

Surface transport includes all the operations necessary to move peat from the excavation site on the bog to the process plant, and is controlled by season, water content of the peat, and a number of other factors. Selection of the optimum surface transport method includes an analysis of the effects of the factors on the technical and economic feasibility of proposed methods.

In this study, surface transport has been considered primarily for drained bogs. Several methods of transporting the peat are possible, and include the following:

- Earthmovers and scrapers
- Railway/monorial/elevated railway
- Tracked vehicles
- Wheeled vehicles
- Conveyor (belt)
- Overhead cable
- Tractor and sleds
- Winch and sleds
- Corduroy road and tracked or wheeled vehicles
- Ice roads and trucks
- Barges

These methods have all been used in the past for transporting peat and/or equipment over peatland. For wet mining, only some of these candidates are likely to be technically acceptable because of the following factors:

- System output required (capacity) - approximately 250,000 t/year of peat at 50% moisture content (medium scale).
- Water content of transported peat.
- Water content of peatland.
- Effect of weather, e.g. heavy rainfall.
- Distance to process plant.

- Location of plant - on or off the bog.
- Transport speed.
- Type of terrain surrounding the peat deposit.
- Surface preparation of peatland along transport path.
- Existing roads, railways, waterways.
- Seasonality - is transport required year-round?
- Length of operating season.
- Ease of re-locating the transport system as the excavation site moves.
- Local transport for pre-processing the peat at the excavation site.
- Loading the peat at the excavation site.
- Handling the peat at intermediate points along the transport route (e.g. transfer from barge to truck).
- Unloading the peat at the process plant, compatibility with storage facility.
- Manpower requirement.
- Need for special skills and training to operate.
- Equipment availability - conventional machinery or custom design and build.
- Variety of equipment used, including maintenance skills, spare parts inventory, and need for service facilities.

When these factors are used in a comparative analysis of the transport system candidates, a system of trucks travelling on a prepared roadbed offers a good possibility of being a viable surface transport system. As a concept, it is compatible with the rest of any peat handling system, is versatile, reasonable in cost, and can be adapted to different lengths of operating season. It also shows promise of being usable on poorly drained peatland, and does not require specialized equipment or skills.

In order to establish fully the practicality and detailed design and costing of such a system, a pilot scale test operation is suggested.

PART 6

ECONOMIC EVALUATION OF ALTERNATIVE
WET PEAT MINING SYSTEMS

PART 6 - ECONOMIC EVALUATION OF ALTERNATIVE
WET PEAT MINING SYSTEMS

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6.0 ECONOMIC EVALUATION OF ALTERNATIVE WET PEAT MINING SYSTEMS

6.1 INTRODUCTION

This section includes capital and operating costs for mining and transport of peat feedstock to the process plant for two wet peat mining methods which were ranked highest in terms of technical and certain preliminary economic factors. The two methods selected for derivation of preliminary cost estimates include:

- a) Bulk Peat Excavation by Amphidredge, a small-scale mining method producing a feedstock to the process plant, at the equivalent rate of about 50,000 tonnes per year of 50% moisture content fuel peat.
- b) Slurry Pump Dredge system, a medium to large scale mining method producing a feedstock to the process plant at the equivalent rate of 250,000 to 500,000 tonnes per year, 50% moisture content fuel peat. A single equipment set will be costed having a production rate of about 250,000 tonnes per year, (50% moisture content), although it is expected actual use would be in sets of two or more feeding a common collecting reservoir for further pumping in a single pipeline.

6.2 CAPITAL AND OPERATING COST ESTIMATE FOR BULK PEAT EXCAVATION BY AMPHIDREDGE

The capital cost estimate is based on a preliminary equipment list of actual machinery currently available from Europe and North American suppliers, including the Amphidredge machine. Although a small Amphidredge is referred to as loading the excavated peat into a hopper on board a large Amphidredge in Section 3, for purposes of cost estimating the larger Amphidredge has been replaced by an air-cushion barge since the large Amphidredge model is a prototype machine discussed only in concept in this report, and accurate cost data were not available. Although it is expected that the air-cushion barge could perform the same basic functions as the large Amphidredge, it is expected that the larger Amphidredge would prove more flexible and manoeuvrable.

The preliminary capital cost estimates have been based on manufacturers budget prices for the various pieces of equipment. Operating cost estimates were based on hourly operating cost information and certain experienced cost data in our files. Where information on the operating characteristics of wet peat mining equipment was not available, assumptions based on experience were made.

The Amphidredge equipment has been selected for the undrained peatland case. No prior surface preparation has been assumed for this example, which will be valid for certain cases. The pumping distance assumed is 1-1/2 to 2 km.

621 CAPITAL COST ESTIMATE

Table 6-1 lists the basic equipment items proposed for the small-scale bulk peat excavation by Amphidredge method and the installed capital costs, in early 1983 \$. Engineering costs, contingency allowance, sales taxes (which are not expected to apply to mining activities) and duties have not been included.

622 OPERATING COST ESTIMATE

- For purposes of estimating operating costs a 260 day operating season has been assumed for a typical Canadian wet peat mining situation. Considering allowances for holidays, days lost and planned maintenance, the total scheduled hours assumed for the bulk peat mining by Amphidredge system is 5600 hours annually (3 shifts/day, 7 days/week). Equipment availability is estimated at 80%, based on experience, resulting in approximately 4480 operating hours per season. The seasonal (annual) production calculation includes a further operating efficiency factor. Based on current hourly labour rates and maintenance and service costs, annual operating costs (in early 1983 \$) expected to be:

- Annual Operating and Maintenance = \$615,000 (includes operators
Labour Costs and foremen only)

Annual Maintenance and Service Costs = \$540,000 (including parts and supplies for the air-cushion barge equipment, Amphidredge and pipelines, etc.)

623 ANNUAL PRODUCTION RATE

It is expected that the annual production rate of the bulk excavation by Amphidredge equipment set will range from 40,000 to 60,000, 50% moisture content equivalent tonnes. For purposes of calculating unit operating costs, an assumed annual rate of 50,000 tonnes (50% moisture content) will be used.

Table 6-1 Capital Cost Estimate - Bulk
Peat Excavation by Amphidredge

Item	Description	Total Installed Cost (early 1983 \$)
1	H-400-4 Amphidredge incl. backhoe/clam and oversize bucket	270,000
2	Air-cushion barge c/w diesel engines, winch, base plates, spud, covering, (50 ton payload)	400,000
3	Additional diesel engines (2)	60,000
4	Hydraulic pumps	46,800
5	Hydraulic motors	54,900
6	Peat Slurry Pump (200-250 cubic meters/h)	22,200
7	Water Pump (110 cubic meters/h)	9,800
8	Rader disc screen system	120,000
9	Belt conveyor (out feed)	31,300
10	Hopper-feeder assembly	40,000
11	Slurry tank (25 cubic meters)	7,900
12	Pipe: standard slurry 18" dia. steel, 2,500 ft. pontoon pipe 18" dia. steel, 2,500 ft. water pipe, 6" dia. steel, 100 ft.	53,100 156,000 1,600
13	Couplings	11,300
14	Pontoons (50)	250,000
15	Push-boat	20,000
16	Split barges (15 cubic meters) (2)	29,100
17	Generator (64 kw)	25,000
18	Fuel tank, automatic controls, welder, tools, spares, misc.	21,000
Total Estimated Capital Cost of Equipment:		\$1,630,000

624 LEVELIZED UNIT COST

To provide meaningful comparisons between the systems being investigated and systems analysed by others, the capital and operating costs have been combined using various economic criteria to produce a unit cost in \$ per tonne. To account for future cost escalation and to give an indication of the project lifetime unit costs, a levelized unit cost has been calculated. The levelized unit cost is the level, or uniform cost per tonne that is equivalent (considering the time value of money) to the varying costs estimated to occur over the comparison period. The levelized unit cost is calculated by dividing the total present worth of project costs by the total present worth of project outputs in tonnes.

A levelized unit cost per tonne was calculated for the bulk peat excavation by Amphidredge system based on the following assumptions:

- estimated capital cost of \$1,630,000,
- working capital allowance of 1/12 of annual operating costs,
- annual operating costs of \$1,155,000,
- a return on investment of 20% (before tax),
- a 20 year project life at 50,000 tonnes (50% m.c.) per year,
- no allowance for capital replacement during the project life, and
- constant price levels and a real discount rate estimated for this analysis to be 6%.

The levelized unit cost calculated for the bulk peat excavation by Amphidredge based on the above assumptions was calculated to be \$30.20/tonne (50% moisture content). The levelized unit cost is the same as the first year unit cost since it is assumed production levels do not vary over the project life.

6.3 CAPITAL AND OPERATING COST ESTIMATE FOR THE SLURRY PUMP DREDGE SYSTEM

631 CAPITAL COST ESTIMATE

The capital costs presented herein are prepared from a preliminary equipment list and manufacturers budget price quotations. Table 6-2 lists the basic equipment proposed for the slurry pump dredge system and the installed capital costs in early 1983 \$. Engineering costs, contingency allowance, sales taxes (which are not expected to apply to mining activities) and duties, have not been included.

Table 6-2 Capital Cost Estimate -
Slurry Pump Dredge system

Item	Description	Total Installed Cost (early 1983 \$)
1	Air-cushion barge c/w diesel engines, winch, base plates, covering (50 ton payload)	400,000
2	Two additional diesel engines	87,200
3	Hydraulic pumps	64,000
4	Hydraulic motors	100,300
5	Mining peat slurry pump (1100 cubic meters/h)	50,000
6	High pressure water pump (500 cubic meters/h)	43,000
7	Hydromonitors, set of 4 (275 cubic meters/h, each)	55,000
8	Stump removal crane (e.g. SK 7040)	43,000
9	Mining slurry pump hoist	24,000
10	Booster peat slurry pump (1100 cubic meters/h)	35,500
11	Pipelines: slurry, 30" dia, steel, 9850 ft. water, 8" dia, steel, 650 ft.	379,500 8,000
12	Couplings	52,000
13	Generator (64 KW)	25,000
14	Fuel tank, automatic controls, welder, tools, spares, misc.	27,500
Total Estimated Capital Costs:		\$1,394,000

The slurry pump dredge system requires peatland surface preparation prior to mining. The amount of preparation is less than for dry mining techniques but does include surface clearing and disposal of trees and shrubs, etc., main, intermediate and field ditching, and installation of culverts. Surface preparation costs will vary but for a typical situation (i.e. about 50 ha per year during production years) it is expected to cost about \$100,000 per year during the pre-production period (3 years) and \$100,000 per year during the production period. The pre-production peatland preparation costs are assumed to be capitalized.

The slurry pumping distance for the equipment selected is about 2 to 2-1/2 km to the nearby process plant or slurry booster pump station.

632 OPERATING COST ESTIMATE

For purposes of estimating operating costs the same length of production season assumptions used in Section 622 is made here, i.e. 5600 annual scheduled hours and 4480 annual operating hours. Based on current hourly labour rates and maintenance and service costs, annual operating costs are expected to be:

Annual Operating and Maintenance Labour Costs = \$645,000 (includes operators and foreman, no staff)

Annual Maintenance and Service Costs = \$555,000 (including parts and supplies for the air-cushion barge equipment, pipelines, etc.)

Annual Surface Preparation Costs = \$100,000

633 ANNUAL PRODUCTION RATE

It is expected that the annual production rate of the slurry pump dredge equipment set outlined in Section 631 will be about 250,000, 50% moisture content equivalent tonnes.

634 LEVELIZED UNIT COST

A levelized unit cost per tonne was calculated for the slurry pump dredge system based on the following assumptions:

- an estimated capital cost of \$1,394,000,
- a working capital allowance of 1/12 annual operating costs,
- a 3 year pre-production period, with no output assumed and \$100,000 annual peatland development expenditure,
- annual operating costs of \$1,300,000,

- a return on investment of 20% (before tax),
- a 20 year project life at 250,000 tonnes (50% m.c.) per year,
- no allowance for capital replacement during the project life, and
- constant price levels and a real discount rate estimated for this analysis to be 6%.

The levelized unit cost calculated for the slurry pump dredge system based on the above mentioned assumptions was calculated to be \$6.68 per tonne (50% m.c.). Again, the levelized unit cost is the same as the first year cost since it is assumed production levels do not vary over the project life.

6.4 SUMMARY OF COSTS

Table 6-3 below summarizes capital, operating and unit cost information for the two systems studied. It is noted that the capital

Table 6-3 Summary of costs for the Bulk Peat Excavation by Amphidredge System and Slurry Pump Dredge System (1983 \$)

System	Initial Capital Costs (\$) (1)	Annual Operating Costs (\$)	Levelized Unit Cost \$/tonne (50% moisture content)
1. Bulk Peat Excavation by Amphidredge (Undrained Peatland)	\$1,726,250	\$1,155,000	\$30.20
2. Slurry Pump Dredge System (Drained Peatland)	\$1,800,250 (2)	\$1,300,000 (2)	\$ 6.68

- (1) Includes working capital
 (2) Includes peatland preparation

costs for the lower capacity bulk peat excavation by Amphidredge System is somewhat higher than the slurry pump dredge system. This reflects the equipment requirements for operating on undrained peatland. Operating costs are about the same due to a similar size of workforce and similar size of power requirements. Since annual

production capacity with the Amphidredge equipment is about 1/5 that of the slurry pump dredge equipment, unit costs are about five times as high.

The Dravo and Kesmark reports, discussed briefly in Part 1.1.1, included information on costs of peat production. Since the assumptions and methods of economic analysis used were different in all reports (including this report), a direct comparison cannot be made. Some comments are included herein for the purpose of indicating the effect of economies of scale and the effect of varying slurry concentrations. Dravo reported unit costs (capital and operating, in 1981 \$U.S.) of \$22.58/ton, \$12.83/ton and \$15.66/ton (dry ton basis) for harvesting and stockpiling of peat using the cutterhead dredge equipment in mid-west peatland conditions at slurry concentrations of 1%, 2% and 3%, respectively. The increased unit cost at 3% reflected (according to Dravo) the expected considerable higher head losses involved in increasing slurry concentration from 2% to 3% solids (by weight).

The Dravo study included the following assumptions on ownership costs:

- straight line depreciation,
- debit/equity ratio 75:25,
- interest on debt 9%,
- return on equity 15% (after tax), and
- Federal Income Tax of 48%.

The Dravo unit costs also included the costs of stackers/reclaimers for the peat storage facility, surface support facilities such as maintenance shop, warehouse, office, etc., and all supervisory staff. The annual production rate considered was 19 million tons of 50% moisture content peat per year. Another site was also costed by Dravo for the 2% slurry concentration situation only. The unit cost for harvesting and stockpiling peat was reported at \$19.94/ton (dry basis) for a smaller scale operation.

The Kesmark report (issued March 1982) included costs for three peatland development scenarios at different locations in Ontario with varied annual production capacity:

- Site 1 - 1,500,000 tonnes/year (dry basis)
- Site 2 - 1,400,000 tonnes/year "
- Site 3 - 670,000 tonnes/year "

The unit capital and operating costs to deliver a 7-8% solids by weight peat slurry to a process plant (using cutter-suction dredge equipment) varied from \$4.52/tonne, \$3.30/tonne to \$3.32/tonne for sites 1, 2 and 3, respectively (all tonnages reported at 0% moisture content). Included in ownership costs were interest on funds at 15%, royalty at 20 cents/tonne, insurance and provision for construction of surge capacity storage.

In making a qualitative comparison of the three studies it should be noted that the Monenco evaluation is based on small-scale peat mining developments, and even the scale referred to as large scale in this report is considerably smaller than the production quantities envisaged in the Dravo report.

It is expected that the numbers, although not directly comparable, do give some indication of economies of scale (e.g. the Monenco and Dravo unit costs). It is expected that the single bulk peat excavation by amphidredge equipment set represents about the least amount of annual production which could be considered for an industrial peat operation (50,000 tonnes/year, 50% moisture content). Costs decrease significantly using the slurry pump dredge equipment set with increased output capacity. The relatively low Kesmark costs give an indication of the effects on costs when the assumption of pumping a relatively high peat slurry concentration (7-8% by weight) is assumed.

It should be noted that the unit costs quoted are only the costs of producing a slurry, re-stated in equivalent dry (or 50% moisture content) tonnes (assuming a 100% recovery of peat from the slurry) for purposes of bases of comparison. No costs are included for the process equipment to achieve the lower moisture content.

6.5 COMPARISON OF WET AND DRY PEAT MINING METHODS

A number of advantages are apparent when considering wet peat mining methods as compared to dry mining techniques. They are based on the premise that peat in a slurry form is a useful mined product for further processing and that the overall economics are more favourable. The wet mining of peat does not require solar drying since suitable commercial dewatering processes are anticipated. Therefore, it is not necessary to prepare large drying areas, e.g. surface clearing, rotovating, profiling of fields, etc. plus the considerable maintenance required on drainage systems including culverts.

With slurry pumping, it is not necessary to build railways or roads to transport dry peat to the user or to buy expensive drying equipment such as peat spreaders, pilers, loaders, etc. The milled peat mining method requires a large reserve of equipment for a short season, and sometimes with bad weather all the equipment is idle. Equipment schedules take this into account by specifying a considerable equipment reserve, from which little effect is achieved. A large labour force is generally required for dry mining methods, to prepare

the bog and to operate and maintain equipment which is not required with wet mining systems.

Wet mining systems do not require on-bog storage, since the slurry can be pumped directly to the plant process. On-bog storage requires consideration regarding customer deliveries. If a dewatering plant is used in conjunction with the wet mining system, it can be operated year round. The actual mining season is expected to be considerably longer with wet mining methods than with conventional dry mining techniques; it is estimated to be about 260 days per year for typical Canadian locations.

Wet peat mining is possible for all types of peat deposits and all mixtures of peat types at a particular deposit, e.g. from the low humified (sphagnum) top layers to the higher humified bottom layers. Wet mining methods produce a good quality feedstock by mixing all the peat layers throughout the deposit and preparing a homogeneous slurry. Stumps pose much less of a problem.

Present (or recent) dry peat mining methods rely on a short 3-4 month drying season for peat production (e.g. sod, milled, hydro peat, bagger systems). The short production season is a barrier to all current methods used for large scale fuel peat production. If it is possible to lengthen the operating season it can be expected that the overall costs of production will be less when compared to the intermittent (or seasonal) operation.

It was difficult to obtain cost information from actual peat mining methods broken into the separate components (e.g. only the mining operation, transport from the mining site to the drying area, transport from the drying area to the end user) which was required to be able to compare wet mining and dry mining economics. In this case, certain European information has been referred to in part, which although not directly transferable to the Canadian situation, should still serve to illustrate order-of-magnitude differences. Table 6-4 shows a comparison of major technical and economic factors between the wet peat mining applications and existing conventional dry mining techniques. It can be seen that the practical yield/ha is about the same for the various methods although lower with the Amphidredge equipment since the moisture content of the starting material (raw peat) is higher (about 96% moisture) than for drained peatland.

Wet mining methods also show a considerable advantage in output and reduced surface disturbance in comparison with dry mining techniques.

Table 6-4

Comparison of Technical and Economic Factors between Wet and Dry Mining Methods
(for Mining and Transport of Peat to Drying Fields or Process Plant)

PARAMETERS	Monenco		Actual Dry			
	Wet Methods		Mining Methods (1)			
	Amphi- dredge	Slurry Pump Dredge	Milling (Ridge)	Bagger	Hydro- peat (N.S.)	
1.	2.	3.	4.	5.	6.	
1. Seasonal production of one equipment set (tonnes air-dried peat, 33% moisture content). (2) (3)	35,000	182,500	15,000	22,000	36,000	
2. Practical yield in tonnes of air-dried peat (33% moisture content) from one cubic meter of raw peat. (2) (3)	0.05	0.11	-	0.14	0.13	
3. Total surface area requirements (ha per 1000 tonnes air-dried, 33% m.c. peat) including mining and drying areas. (2) (3)	1.1	0.6	4.0	6.0	7.0	
4. Seasonal manpower requirement for mining and transport of peat from the bog to drying area or process plant, manshifts per 1000 tonnes air-dried peat, 33% m.c. (3)	0.40	0.10	0.25	0.7	1.0	
5. Total weight of set of equipment per 1000 tonnes production of air-dried peat, 33% m.c., including mining and transport of peat to drying fields or process plant. (3) (4)	1.8	0.3	0.4	2.5	7.0	
6. Total power requirement, installed kw per 1000 tonnes air-dried 33% m.c. peat for mining and transport to drying fields or process plant. (3) (4)	10.1	4.4	2.0	12.0	22.0	

NOTES:

- (1) Dry mining information from "Peat Reference Book" edited by Samsonov, N.N. and Co., Energiya Publishing House, Moscow-Leningrad, 1954
- (2) For highmoor type peat deposits average degree of decomposition 20-25%, stumps content more than 1%.
- (3) 33% moisture content selected for ease of data comparison.
- (4) Wet methods do not include dewatering; dry methods do not include stockpiling, loading or transfer of peat on the mine area.

APPENDIX A

AN INVESTIGATION OF THE RHEOLOGY
AND PUMPING OF PEAT-WATER SLURRIES

**APPENDIX A - AN INVESTIGATION OF THE RHEOLOGY AND
PUMPING OF PEAT-WATER SLURRIES**

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A.0 AN INVESTIGATION OF THE RHEOLOGY AND PUMPING OF PEAT-WATER SLURRIES

A.1 INTRODUCTION

As part of the "Evaluation of Alternative Wet Peat Mining Systems" study, Monenco sub-contracted a small laboratory study of two raw peat samples (one from Ontario, one from Saskatchewan) to Chemical Engineering Research Consultants Ltd., for rheological testing. The results were used by the sub-contractor to predict likely single-stage pumping distances for peat slurry. From a scientific approach the results are interesting and for the sake of completeness of this investigation, an abbreviated version of the findings follows. However, it was found that the main source of information, the industrial peat slurry data from Europe, could not be readily correlated to the preliminary laboratory findings without more extensive testing. Therefore, from a practical point, the laboratory test data could not be integrated into the study, although some of the general findings (such as maximum pumping distance) compared favourably to previous peat pumping experience.

A.2 RHEOLOGICAL CHARACTERIZATION

For the purposes of this investigation, two peat samples, one from Ontario and one from Saskatchewan, were prepared (treated in a hydropulper) and subjected to rheological testing by Chemical Engineering Research Consultants during October, 1982 on behalf of Monenco Limited. The Ontario sample (Parry Sound) was a sphagnum-cotton grass peat about H6 humification and the Saskatchewan sample (Buffalo narrows area) was a sphagnum sedge peat with some shrubby remnants about H6 or H7 humification. The slurry rheology was studied using a Fann concentric cylinder viscometer. The rheological data from the tests and the correlation for pipeline flow of Bingham plastics were examined together with other methods for determining velocity, viscosity and solids concentration to calculate pipeline diameter and pumping distances.

The test data obtained for the Saskatchewan and Ontario peat slurries is included as Figures A-1 to A-6. Shown is shear stress plotted as a function of shear rate with peat slurry concentration as the parameter. The slurry was shown to be non-Newtonian; there was definite evidence of a yield stress and at the higher concentration a non-linear relationship between shear stress and shear rate. At a given concentration the apparent viscosity of the slurry decreases with increasing shear rate and this is no doubt a reflection of the further separation and alignment of fibers under shear. While it would be possible to develop comprehensive rheological equations to describe the behaviour of the slurries, it was decided by the investigators at this stage it would be appropriate to interpret the

behaviour in terms of the relatively simple Bingham plastic model which involves only two parameters, the yield stress, T_y , and the plastic viscosity, n . Each set of data in Figure A-1 and A-2 has therefore been fitted with a straight line from which the effective T_y and n values were calculated. These are shown in Figures A-3 and A-4 for the Saskatchewan peat and in Figures A-5 and A-6 for the Ontario peat. The data are highly consistent in both cases and give confidence that the laboratory testing procedure was appropriate and that the results are reproducible. The smooth curves drawn through these data were used to provide effective yield stress and plastic viscosity values as a function of concentration, as listed in Tables A-1 and A-2 for the Saskatchewan and Ontario peats, respectively.

In order to at least partially explain the markedly different consistencies of Saskatchewan and Ontario peat slurries at the same concentration, the residual ash and other inorganic solid content was determined by firing peat samples at 600 degrees C. While the Saskatchewan peat contained only 3.7% solid residue (expressed as a percentage of the dry peat), the Ontario peat contained 12.9%, part of which was clearly siliceous in origin. This indicates that the Ontario peat contained relatively less fibrous material. This in turn accounted, at least in part, for the lower consistency of Ontario peat slurry compared with the Saskatchewan peat slurry at the same concentration.

The laboratory investigation confirmed that the various peat characteristics (such as peat type, slurry solids content, degree of decomposition) are important in determining flow characteristics for the peat slurry (i.e. shear rate, yield stress) as previously discussed in Section 234.

Table A-1 "Smooth Curve" Effective T_y and n Values for
Saskatchewan Peat Slurries taken from Figures 3-5 and 3-6

Peat Concentration (% by weight)	T_y (N.m-2)	n (cp)
2	1.5	5.4
4	3.2	17.0
6	6.0	41.0
8	30.0	105.0

Table A-2 "Smooth Curve" Effective T_y and n Values for Ontario
Peat Slurries taken from Figures 3-7 and 3-8

Peat Concentration (% by weight)	T_y (N.m-2)	n (cp)
6	2.0	22.0
8	5.6	37.0
10	19.5	62.0
12	51.0	107.0

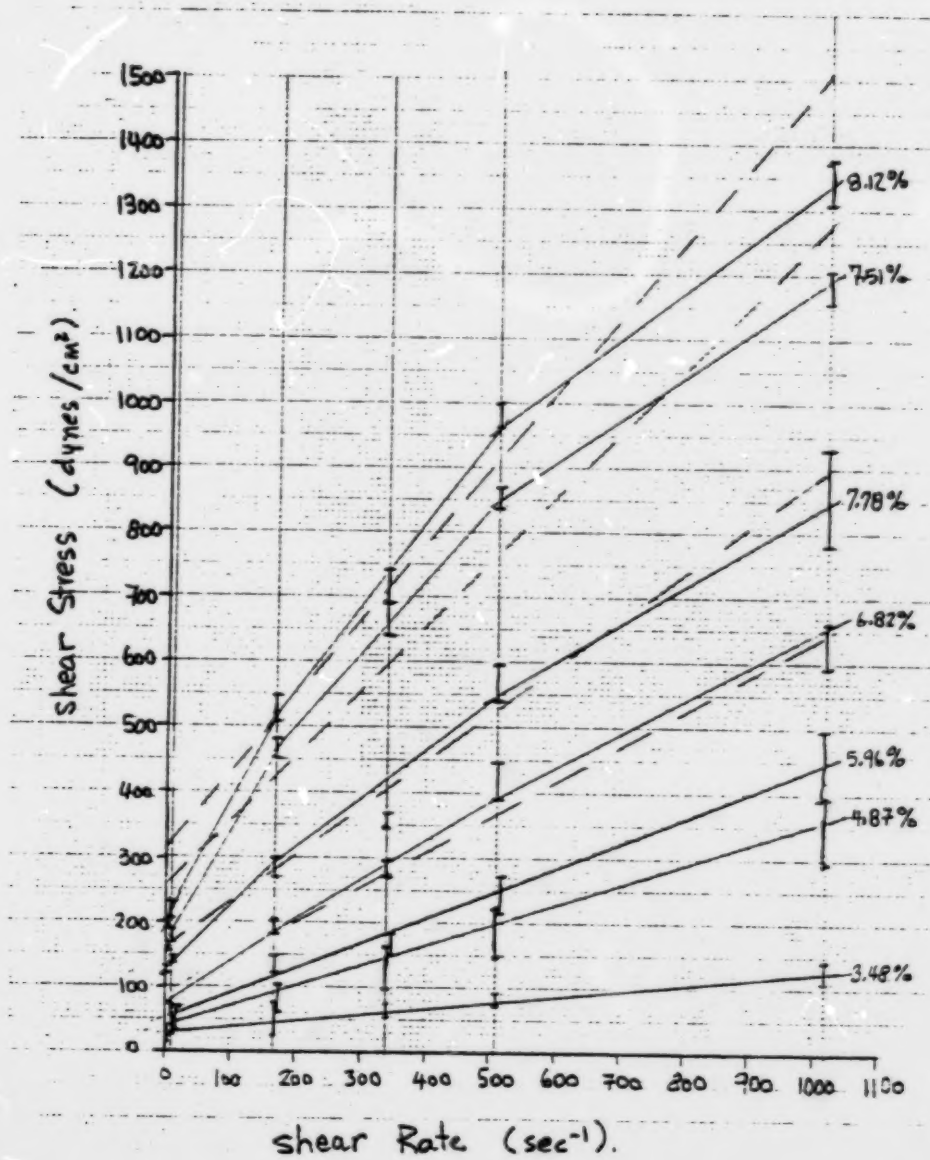


Figure A-1 Rheological data for Saskatchewan peat slurries.

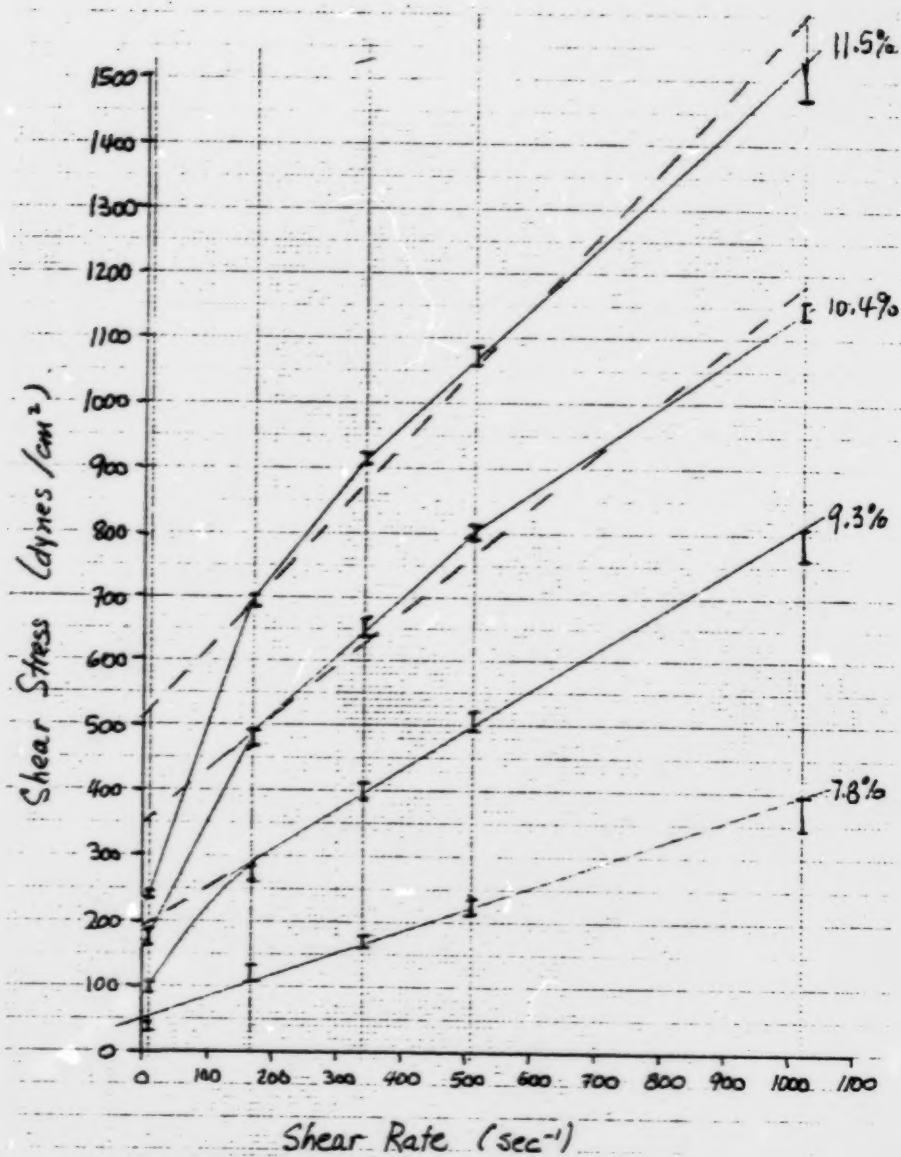


Figure A-2 Rheological data for Ontario peat slurries.

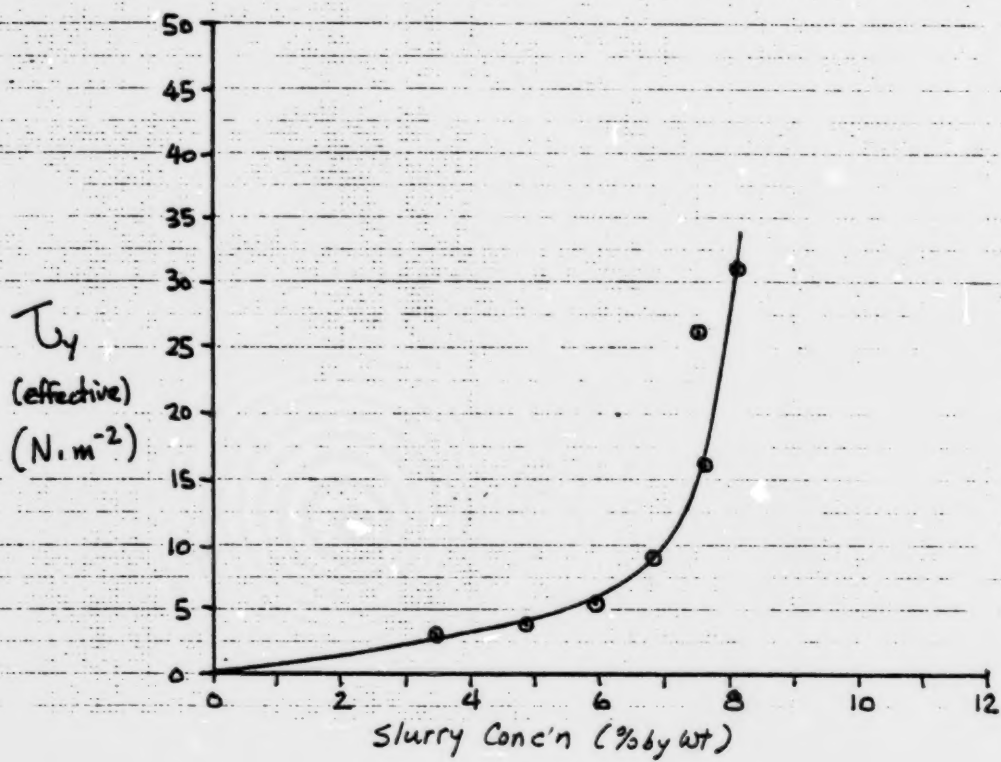


Figure A-3 Effective τ_y values for Saskatchewan peat slurries.

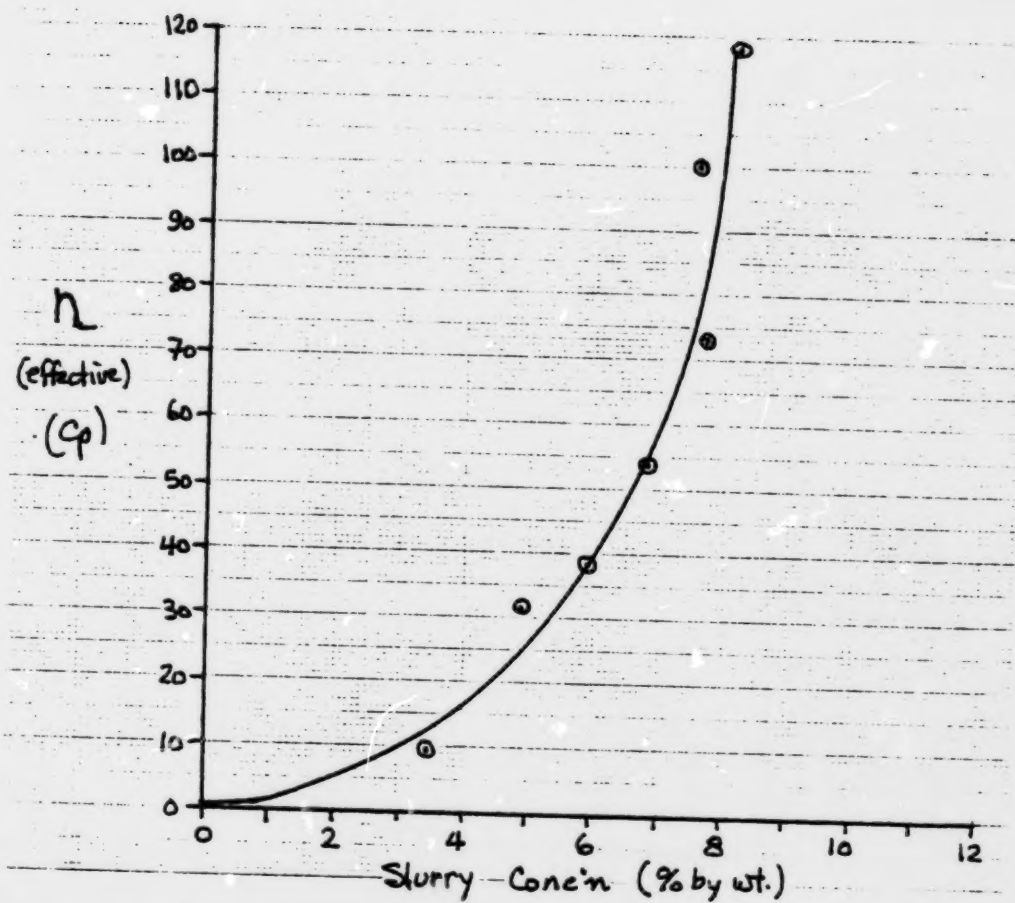


Figure A-4 Effective η values for Saskatchewan peat slurries.

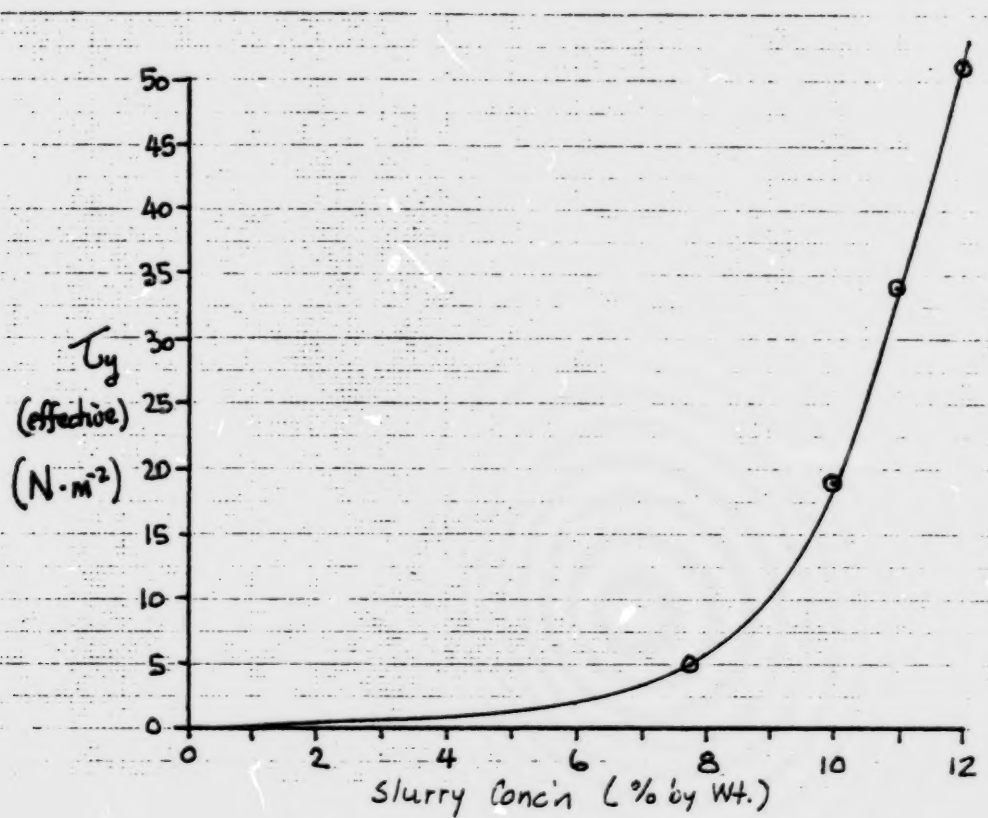


Figure A-5 Effective τ_y values for Ontario peat slurries.

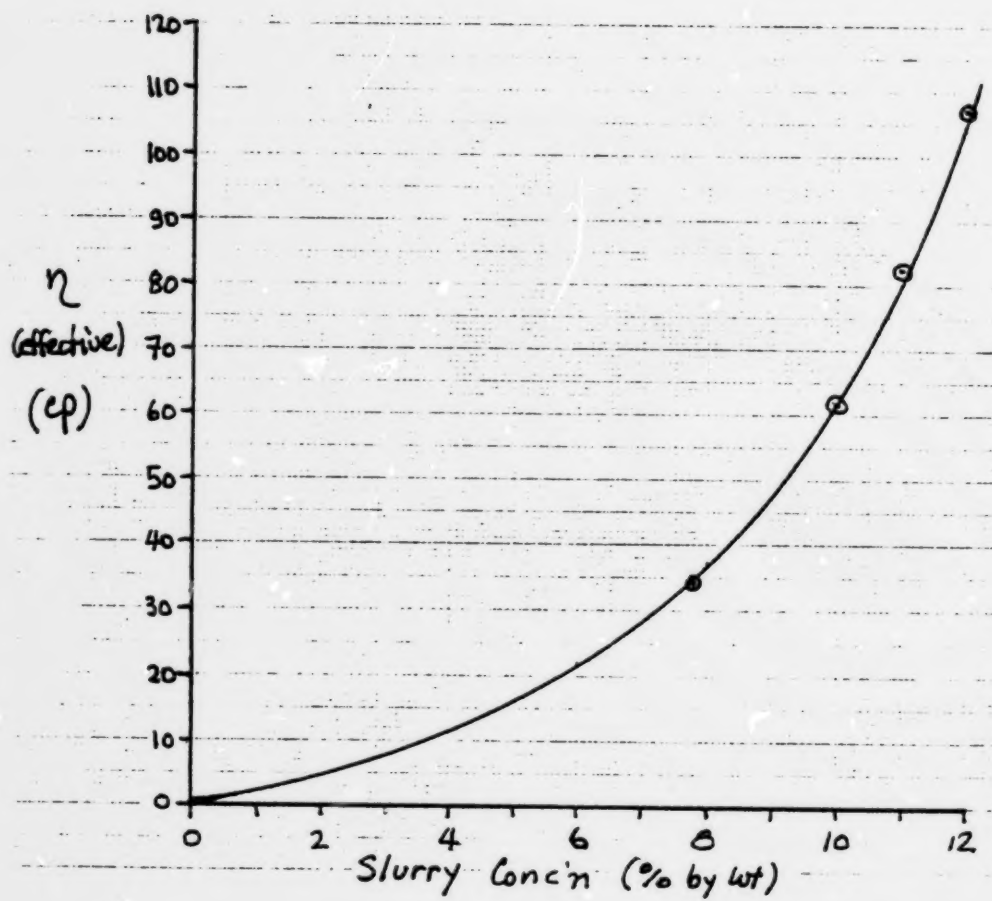


Figure A-6 Effective η values for Ontario peat slurries.



APPENDIX B

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REFERENCES

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